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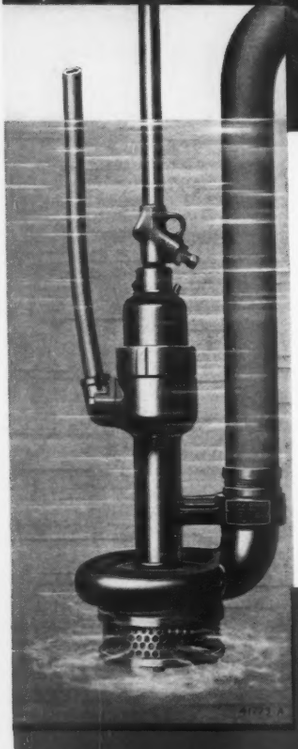

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Compressed Air Magazine

NOVEMBER, 1935

Volume 40 Number 11

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Annual subscription rate: Domestic, $3.00; foreign, $3.50. Single copies, 35 cents.

Manuscripts intended for editorial consideration should be accompanied by return postage.

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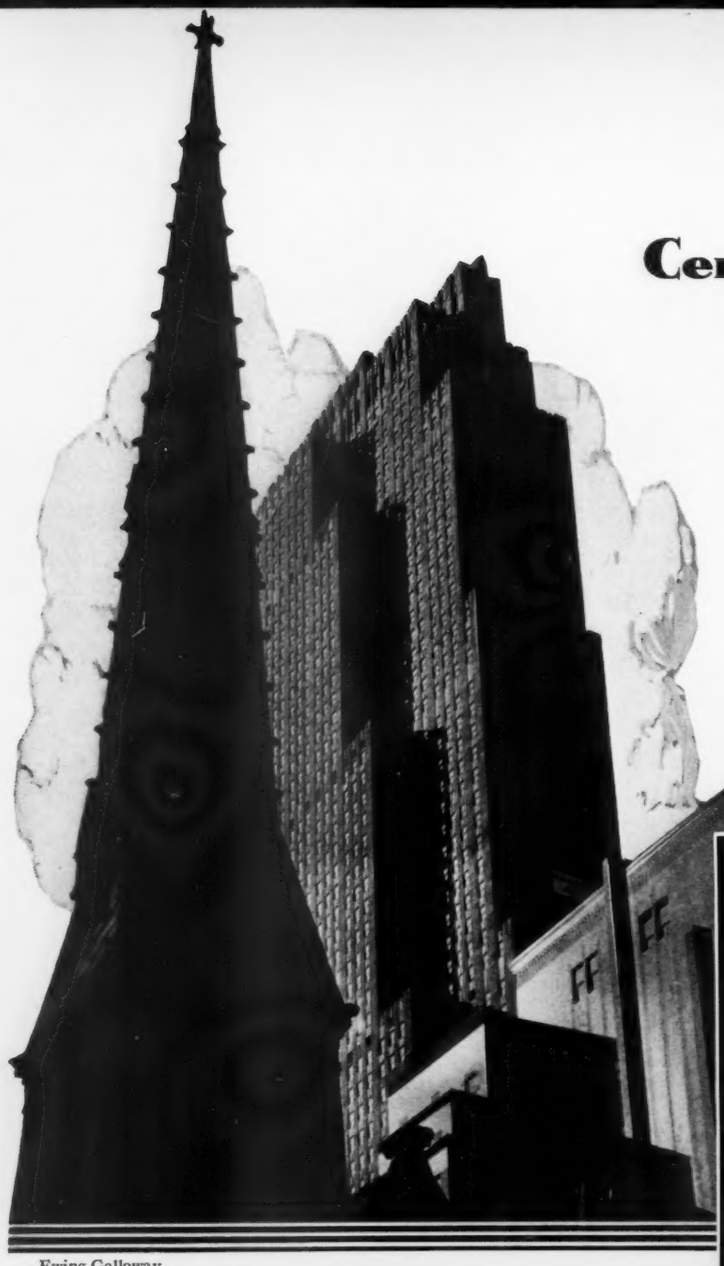
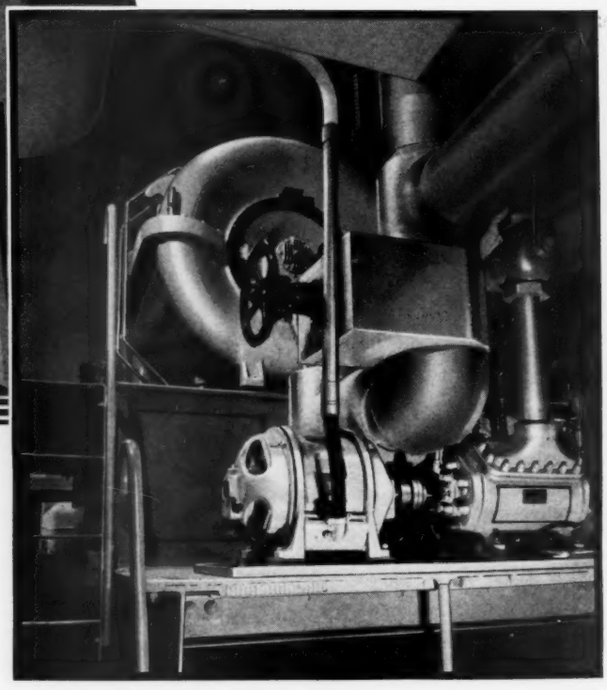
Centrifugal Water-Vapor Refrigeration

A. D. Karr





Ewing Galloway

FIFTY-EIGHT STORIES UP

Offices of the American Cyanamid Company, 750 feet above the street in the R.C.A. Building, New York City, are cooled with the aid of chilled water produced by the 180-ton Ingersoll-Rand centrifugal water-vapor refrigerating unit at the right. It was selected because it was of paramount importance that the thousands of persons in the building be safeguarded from irritant gases, from fire hazards, and from the discomforts of vibration incident to the use of reciprocating machinery. One end of the compressor and, below it, the motor-driven vacuum pump that serves the condenser are shown.

Part 1—Principles

WATER, which is the only refrigerant used in centrifugal water-vapor refrigeration, is universally available and has no appreciable cost. It is a refrigerant that is truly safe, from every aspect. As a refrigerating medium, 1 pound of water in evaporating will effect more cooling—will remove more Btu's—than any other refrigerant. The latent heat of evaporation (at 50°F.) of water, as compared with several widely employed refrigerants, is given in the following table:

	BTU'S PER POUND
Water	1,063.5
Ammonia	527.3
Freon...(F-12)	64.5
Carbon dioxide	86.6
Methyl chloride	169.9
Sulphur dioxide	156.0
Propane	156.0
F–11	80.3
Dichloroethylene	134.7

To cool a pound of water from a condensing temperature of 95°F. to an evaporating temperature of 50° requires the removal of 45 Btu's. This is about 4.2 per cent of the refrigerating effect obtained through evaporation. "Liquid cooling" ceases to be a problem with water-vapor refrigeration. A pound of water may be visualized as a pint—two tumblerfuls. When vaporized at 50°F. it will have a volume of 1,705 cubic feet. This means that that pint of water will be expanded to fill a room 17 feet long, 10 feet wide, and 10 feet high—a large hotel room! It is evident that, regardless of the fact that only 11.3 pounds of water need to be evaporated per hour to give a "ton" of refrigeration, it is wholly impracticable to handle 32,000 cubic feet of vapor per minute in the conventional

RAPIDLY increasing acceptance of water-vapor refrigeration has inevitably stimulated widespread interest in this important development. It is, possibly, not generally appreciated that water-vapor refrigerating machines using mechanical compressors are now available in highly efficient form and that many installations of this type have been made. It is the purpose of this article to review fundamental relationships and principles, and to point to the accomplishments of centrifugal compression as applied to water-vapor refrigeration.

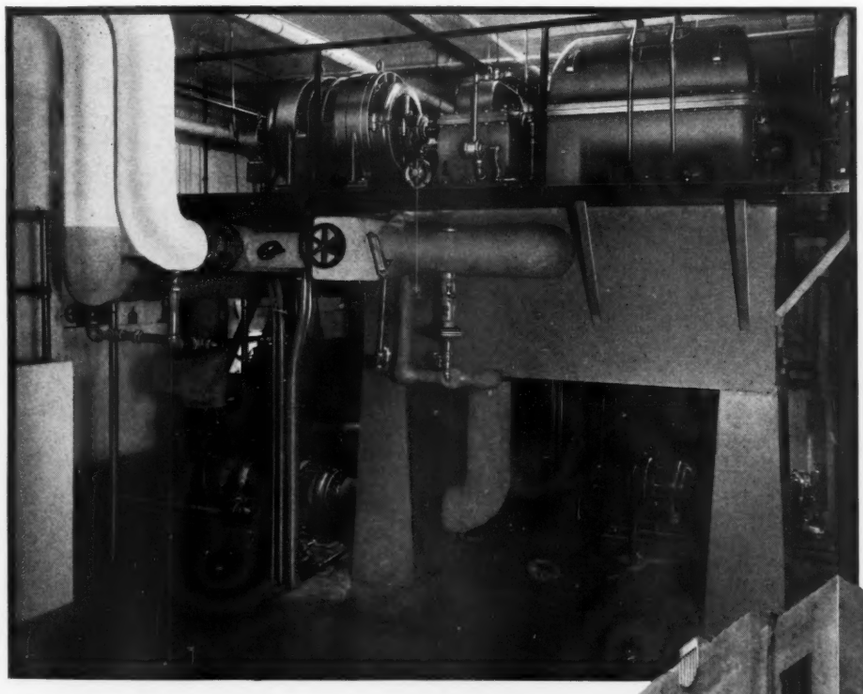
reciprocating compressor to obtain 100 tons of refrigerating effect. This explains in part why the use of water as a refrigerant was so long delayed. A further reason for the fact that the commercial realization of the possibilities of water vapor did not come about sooner may be found in the history of mechanical refrigeration.

Until the introduction of air conditioning with its summertime "comfort-cooling" there was but a very limited demand for the production of moderately low temperatures—that is, in the region between 40° and 55°F. Except for the cooling of drinking water and for a few industrial applications, the majority of refrigerating installations necessitated subfreezing temperatures, and the industry grew up on this basis, with ammonia as the predominant refrigerant.

Comfort-cooling involves the use of large tonnages at moderate temperatures. It created a demand for a safe refrigerant; and new nonirritant refrigerants, together with equipment to employ them, appeared promptly. Meanwhile, steam-jet ejectors had been developed for the removal of air in power plants and for various industrial processes. A steam-jet compressor can, with reasonable economy and in a compact apparatus, move large volumes of vapor from a very high vacuum to the lower vacuum induced in a condenser by the available cooling water. It was only natural that this development should result in refrigeration by the evaporation of water in a flash chamber. This is steam-jet water-vapor refrigeration, or, as it is sometimes called, "vacuum cooling." Units of this type are now being built on a commercial basis and are made up of a number of thermal compressors or "boosters" ranging in refrigerating capacity from a fraction of a ton to 150 tons each.

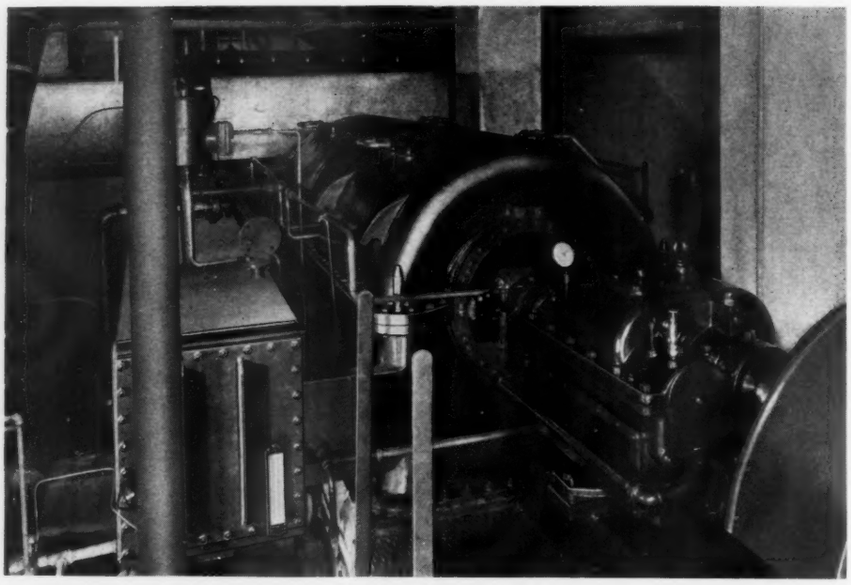
In water-vapor refrigeration the cycle followed is exactly the same as that in the older compression-refrigeration systems. Water is evaporated, compressed as a vapor, delivered to the condenser, and liquefied at a higher pressure. In the usual range of temperatures the working pressures are astonishingly low. Evaporation at 50°F. takes place when the absolute suction pressure is reduced to 0.363 inch of mercury. This corresponds to a 29.637-inch vacuum or to 0.178 pound per square inch absolute. The vapor is compressed to 0.8149 pound per square inch when condensing at 95°. This is a compression ratio of about 4.5 to 1, which will be recognized as reasonable.

Because a very low absolute pressure is required in a water-vapor refrigerating unit, special means are needed to bring about and to maintain this condition. Air and noncondensible gases must be removed and kept out during operation. But, contrary to regular practices with other refrigerants, air is admitted whenever a water-vapor unit is shut down. One does not have to worry about "loss of charge": the re-



FEDERAL INSTALLATION

The Government recently opened an extension to the Federal Warehouse in Washington. The many offices in this structure are cooled by means of two centrifugal water-vapor refrigerating units which have a combined capacity of 300 tons. The motor and the compressor are mounted above the evaporator, and the various service pumps are located on the floor.



TWIN COMPRESSOR UNIT

Installed in 1934 for air conditioning two floors of one of New York City's large department stores. This unit has two compressors arranged in tandem and driven by a single motor. The condenser is at the left of the compressors, which are mounted directly above the evaporator.

frigerant does not have to be drawn off and does not have to be stored in containers during the winter.

Before starting. the vacuum is "pumped-up" by turning on the air ejector or vacuum pump a few minutes in advance. Two types of air-removal equipment are customarily employed. Where high-pressure steam is available, a 2-stage steam-jet air ejector is used with a suitable "inter" and "after" condenser. But when high-pressure steam (50 pounds or higher) is not available, a small rotary vacuum pump direct connected to an electric motor is used for evacuating the water-vapor units.

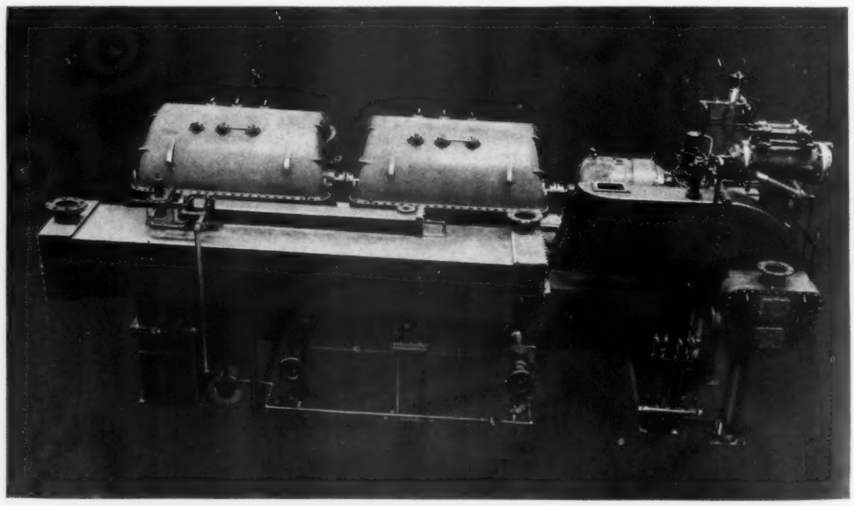
Steam-jet water-vapor refrigerating units were first commercialized for the reasons already outlined. However, in spite of their simplicity and thoroughly effective performances, this type of apparatus has certain inherent handicaps. The most obvious of these is the need of a sufficient supply of steam. The majority of comfort-cooling installations are in buildings where only low-pressure steam is available; and, aside from the objections to operating a heating boiler in the summertime, units designed for low-pressure steam are relatively not economical of fuel or of condensing water. There was, evidently, a potential field for apparatus combining the advantages of water as a refrigerant with mechanical compression of the vapor.

With enormous volumes of vapor to be handled, centrifugal compression seemed to be the logical answer. Intensive development of a special type of centrifugal compressor, or blower, has resulted in a remarkably compact machine of high efficiency and possessing valuable operating characteristics. These characteristics are the outcome of the inherent properties of water as a refrigerant combined with the inherent pressure-volume relationship of a centrifugal compressor. It should be noted here that the development just referred to was undertaken by the Ingersoll-Rand Company, which is one of the leading manufacturers of centrifugal blowers and compressors.

The centrifugal water-vapor machine, when operated at constant speed with no external control or adjustment of any kind, automatically takes power from the driver substantially in proportion to the imposed refrigeration load. The range of such self-regulation, in the majority of applications, is sufficiently broad for all practical needs. Overload capacity is limited, in effect, only by the reserve power available in the driver. Units of this type are being successfully used today in conjunction with air-conditioning — comfort-cooling — installations equipped with no control devices for adjusting the capacity to the load. The chilled-water temperature varies slightly as the load changes, and the degree of this variation essentially meets the requirements of the air-conditioning apparatus. In other words, in a water-vapor refrigerating unit, when used to chill water, the refrigerant inherently produces substantially the correct temperature and does not tend to freeze the chilled water. Although freezing temperatures can be produced, freezing is possible only under exceptional conditions of underload.

Most refrigerants readily give temperatures below 32°F., and special precautions have to be taken to prevent a freeze-up. With water-vapor refrigeration, the whole volume of chilled water is customarily circulated through the evaporator, a small fraction "flashing" off as vapor and thereby cooling the balance. Consequently, no heat-transfer surface is required in the evaporator—as is the case when the refrigerant is not the medium to be cooled—and there is no danger of bursting tubes or of other damage to the equipment even should freezing occur.

Pumps for removing chilled water (and condensate-removal pumps on steam-jet units) operate under practically the same conditions as do condensate pumps serving power-plant surface condensers. As the special problems involved in power-plant



TURBINE-DRIVEN UNIT

A shop view of one of several centrifugal water-vapor machines which have been installed in a leading United States automobile plant. The conditioned air serves two purposes: it increases the efficiency of the workers and it is of aid in various operations that require even temperatures. This unit has twin compressors, both driven by one steam turbine. The condenser for the turbine is the heart-shaped part at the right.

operations have long been overcome, the required type of pumping equipment is, therefore, available.

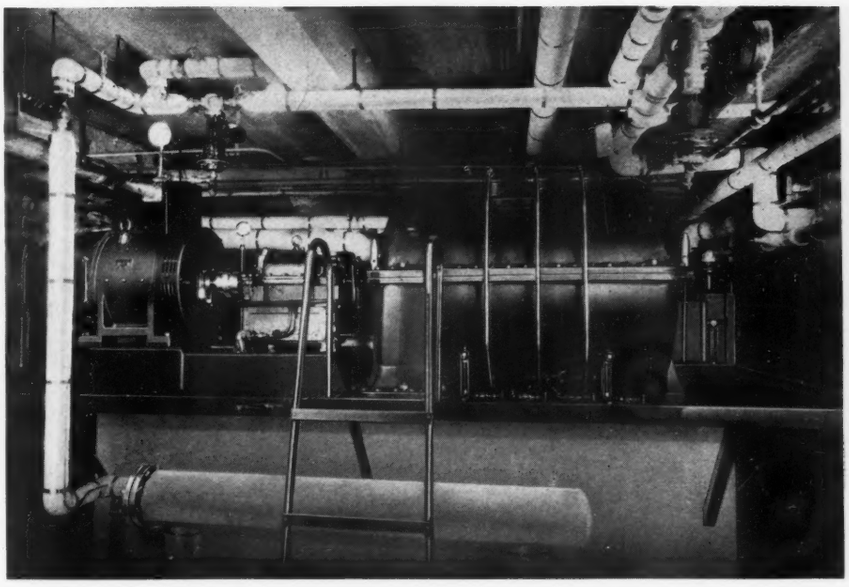
Part 2—Installations

CENTRIFUGAL water-vapor refrigeration may be defined as that type of mechanical refrigeration employing water as the refrigerant and using a centrifugal compressor. A complete unit of this kind includes a compressor, flash-type evaporator, vapor condenser, driver, and an air-evacuating device or "vacuum pump."

The pioneer installation was made in Washington, D. C., early in 1933. This unit has a rated capacity of 75 tons and provides chilled water for the comfort-cooling of a large retail store. It is a single-compressor unit driven through step-up gear by a 60-hp. synchronous motor. The plant was successful from the start, and the machine is now completing its third season of service.

In 1934 four new installations were made. One of these consists of a twin unit having two identical compressors mounted in tandem upon a 2-compartment evaporator and driven through a single step-up gear by a single motor. It will be recognized that this construction makes it possible to obtain a greater range of standard machine capacities with a minimum number of standard compressor sizes, thus favoring economical production. This particular unit was set up in a New York department store for the purpose of cooling water for air conditioning the first floor and basement.

Unique among the 1934 installations, and in many respects the most interesting, is that of 180 tons located on the 58th floor of the R.C.A. Building in Rockefeller Center, New York City, in the American Cyanamid Company offices. It is a single-blower unit driven by a 150-hp. constant-speed induction motor. The requirements that led to the selection of a centrifugal water-vapor refrigerating machine in this case were so exacting as to justify enumeration here:



FOR COMFORTABLE SHOPPING

It has been well proved that air conditioning customers' rooms stimulates sales of all kinds; but it is particularly apropos that a furrier should provide a cool atmosphere for summertime shoppers. The 106-ton centrifugal water-vapor refrigerating unit shown here serves one of Boston's leading fur shops.

1—As the unit was to be placed 750 feet above the street and in an office building occupied by many people, an inflammable or irritant refrigerant could not be used.

2—Steam-jet water-vapor refrigeration was eliminated because it was considered impracticable to deliver live steam to the 58th floor, and also because space was not available for a sufficiently large indoor cooling tower.

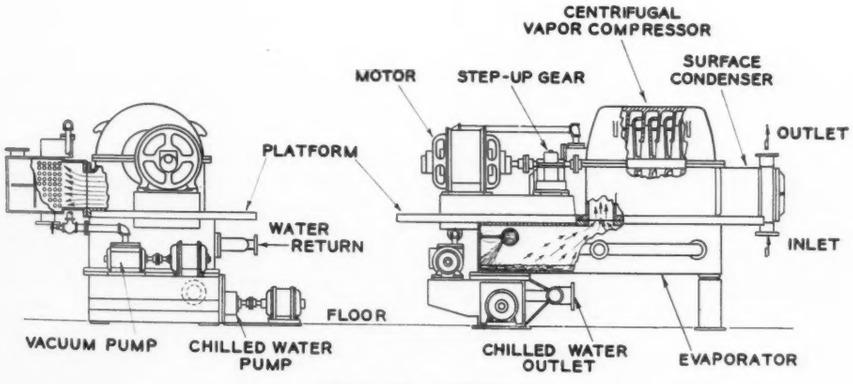
3—A reciprocating compressor of sufficient size could not be employed because of the vibration and its possible transmission to the frame of the building.

Consideration of these various factors convinced the engineers and owners that centrifugal water-vapor refrigeration alone would, first, prevent added hazard in time of fire through the use of a safe refrigerant; second, guarantee freedom from restrictive ordinances covering the use and storage of refrigerants; third, obviate the necessity of transporting and storing the replacement refrigerant. Recalling that the location of the plant is far above the street and in a busy office, it will be apparent that this last item is one of no inconsiderable importance.

In 1934 was made the first industrial application. As the chilled water furnished by this unit had to be employed directly in the work of production, complete reliability was a controlling factor. That this demand has been fully met is evidenced by the subsequent purchase of four larger units of the same type.

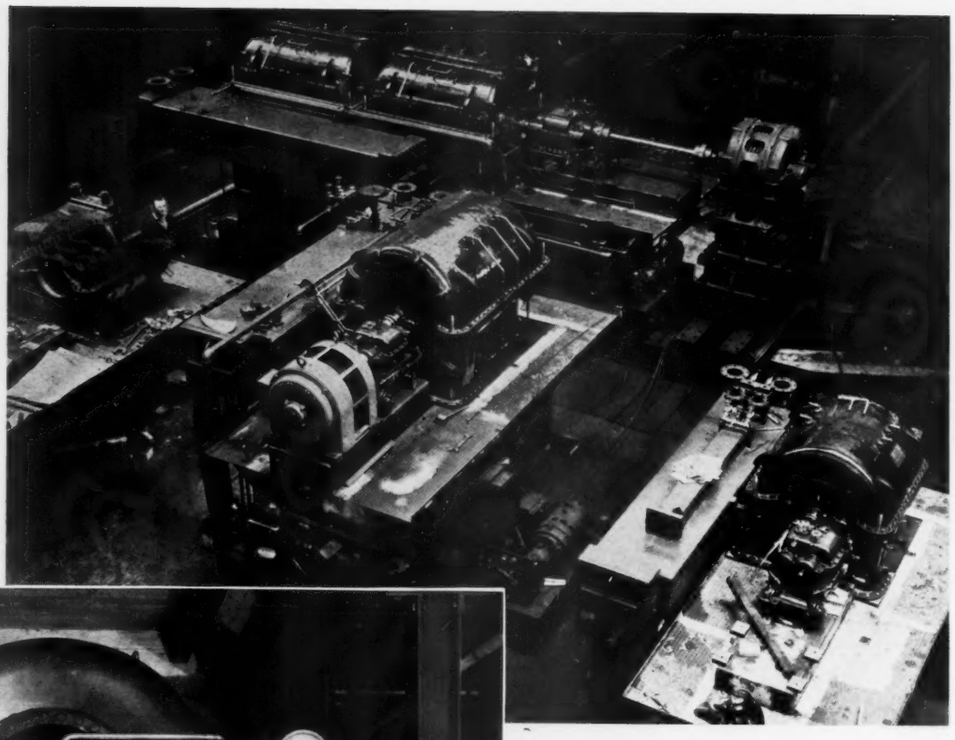
The year 1935 has witnessed the successful installation of numerous large centrifugal, water-vapor refrigerating units for the air conditioning of Government and commercial office buildings, auditoriums, stores, and industrial plants. The phenomenally rapid increase in the number of commercial applications can be explained only by the inherent advantages of this type which uses water alone as the refrigerant and which is characterized by an exceptionally high-grade performance, as earlier installations have amply demonstrated. The significance of this record is heightened when it is realized that a refrigerating unit with a capacity of several hundred tons inevitably represents a substantial investment. Where sums of such magnitude are involved, a purchaser cannot afford to take the risk of making casual experiments with new and untried apparatus.

An important advance in the field in 1935



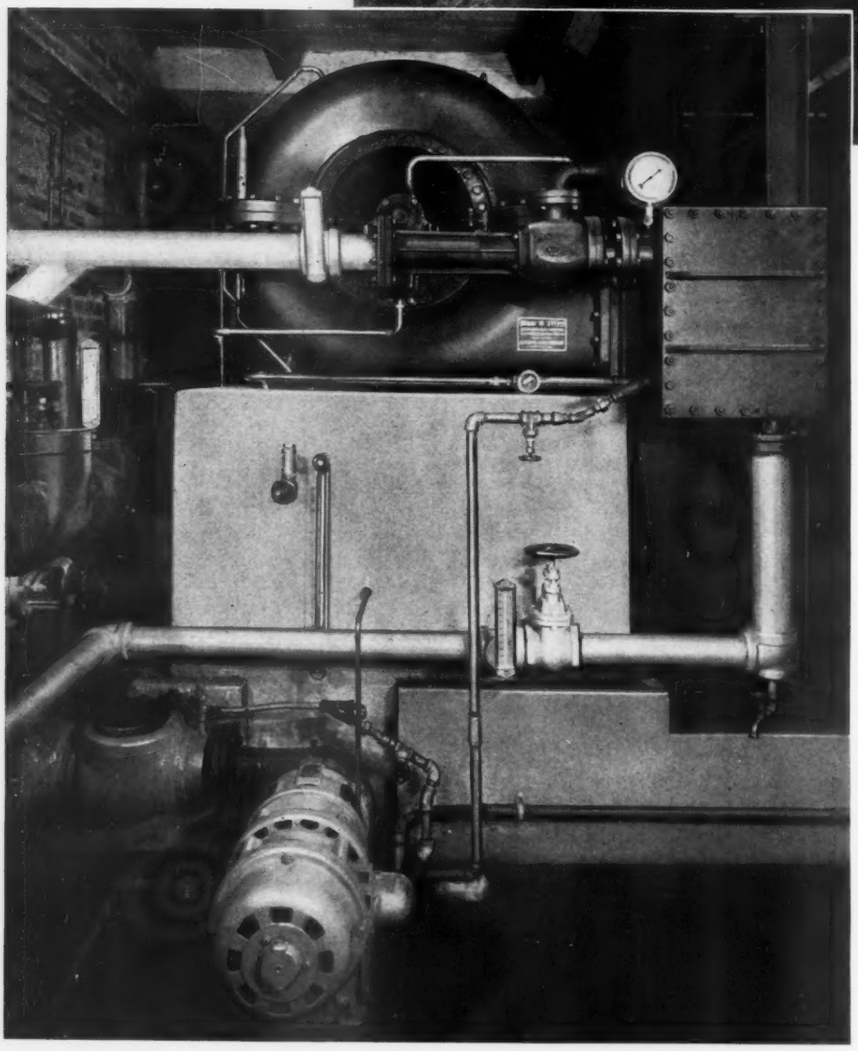
HOW IT WORKS

Water sprayed into the evaporator flashes into vapor by reason of the high vacuum maintained in that compartment. In vaporizing, heat is extracted from the water, which is thereby chilled. The vapor is compressed and is then delivered to a conventional tubular condenser.



IN PRODUCTION AND USE

A group of Ingersoll-Rand, centrifugal water-vapor refrigerating units on the factory assembly floor are shown on the right. Below is the first installation of a unit of this type which has just completed its third season of successful operation in a large department store in Washington, D. C., where it furnishes chilled water for comfort-cooling. It has a single compressor driven by a 60-hp. synchronous motor, and has a rated capacity of 75 tons of refrigeration.



was the placing of several units having direct-connected steam-turbine drive. One of these operates with steam at from 2 to 3 pounds pressure, the others with high-pressure steam. All are fitted with constant-speed condensing turbines. The turbine condensers use circulating water discharged from the vapor condensers, thus effecting a saving in cooling water. The normal speed of the water-vapor type of centrifugal compressor is at a rate that makes for exceptionally low steam consumption on the part of the direct-connected turbines.

Another important improvement is the reduction in over-all headroom that has been made possible by an especially developed pump for the removal of chilled water. This pump is installed directly in a well, which forms one of the supports for the refrigerating unit. A similar support provides a platform for the vacuum pump and also serves as a sump into which all drains are led. This arrangement permits all auxiliary piping to be assembled as an integral part of each unit. Equally careful attention to the many other details involved has resulted in a standardized design that shortens the delivery time, simplifies the foundations and the work of installation, and likewise assures ease of operation.

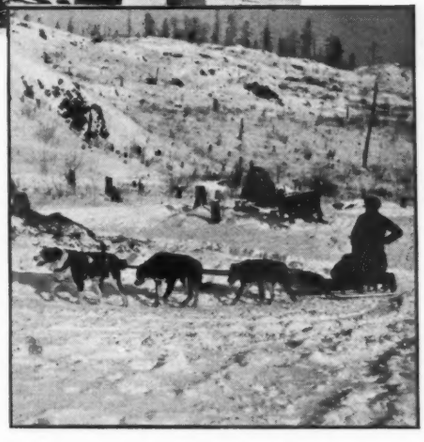
Up to date, centrifugal water-vapor units have been furnished for chilled-water temperatures ranging from 40° to 56°F., and for condensing-water temperatures ranging from 67° to 91°F. Condensing water is taken from city systems, deep wells, cooling towers, or mill-supply lines, as happens to be convenient; and three types of electric-motor drive—direct-current, alternating-current-synchronous, and alternating-current squirrel-cage—can be provided. Constant-speed drive has answered all requirements.

It is inspiring to watch these water-vapor units in course of production in the shops and in actual routine service in the field. Their new and unique characteristics will, doubtless, continue to make an increasingly stronger appeal to the imagination of engineers—for it has always been so with machines that do their allotted tasks uncommonly well.

Thirty Years of Canadian Mining

Northwestern Quebec—Part I.

R. C. Rowe



THREE MODES OF TRAVEL

The advent of commercial flying was a great boon to mining in Quebec. Prior to its coming, travel and freighting were long and laborious procedures. In the early days, mail and light supplies were sometimes delivered in the winter by dog sled, as seen in the lower picture which was taken at the Aldermac Mines, Ltd. Above is a canoe portage on the road to Rouyn in 1926. A plane of General Airways, Ltd., is shown on the Harricanaw River on one of the regular trips to the mines.

I

Which Touches Upon the Early and Late Discoveries

"Out, out! Forever out from man,
Beyond where no Indian broods,
Out where never a life began,
In the grim and tortured woods."
—ALPINE MACGREGOR.

IN THE previous chapters of this history we have followed the development of mining in northern Ontario, and we have traced the northward spread of civilization. A glance at the accompanying map will show that up to the discovery of Kirkland Lake the course was almost due north, whereas we next find it turned in a nearly easterly direction from Kirkland Lake.

The active development of northwestern Quebec almost coincided with the forward march of Kirkland Lake after 1920; but, curiously enough, the first actual discovery of gold occurred in the former region and antedated that in the latter by some years. Another interesting point about northwestern Quebec is that the first metal strike in the Canadian North was made on the Quebec side of Lake Timiskaming. That was the Wright Mine which was noted on Bellins' map in 1744. It was found during one of the journeys made by the old French voyageurs and priests from the St. Lawrence River. Those expeditions traced their way up the great Ottawa River, across Lake Timiskaming, and again up the Ottawa to its headwaters. They were a part of the exploration scheme of the state and church of the old French regime in Canada long before the British came; and they form a chapter of Canadian history that teems with strenuous events and picturesque action. The travels of those early voyageurs into unknown territory infested with hostile Indians were undertaken for the glory of God and the grace of his most Christian Majesty the King of France, and they were feats of almost superhuman courage and unbelievable hardihood. One of them resulted in the discovery of silver with galena on the shores of Lake Timiskaming. We can easily imagine that it created some excitement in those days; but the story of metal mining in Quebec was not to start then.

The next northern development in mining in Quebec came many years later at Chibougamau. Chibougamau really lies a good many miles east of the region with which this part of our chronicle is concerned; but in these days of air travel, Chibougamau, while distant in miles, is near in time. It forms a background for later events; and as it is now coming into a good deal of prominence, some account of it here is proper.

The first intimation of mineral wealth in the Chibougamau Lake area was the arrival of Peter McKenzie in Quebec City with samples he had gathered in the region. That was in 1904. Peter McKenzie was the factor of a Hudson Bay fur post and not a prospector; but he evidently knew something about minerals, for otherwise he would hardly have carried that bag of

MAIN STREET OF ROUYN

A picture taken during the boom days, when Rouyn was such a place as the movies make out all mining camps to be. It was the last of the wide-open Canadian mushroom towns, with a devil-may-care spirit and little thought for tomorrow. Rouyn and Noranda are twin settlements, but the latter has outstripped its neighbor in development.

samples over the long trails to Quebec. So far as can be gathered, his interest was academic, for he apparently made no move to capitalize upon it. He did, however, show his samples to Mr. Obalski who was at that time Inspector of Mines for the Province of Quebec.

In 1905 Mr. Obalski made a journey into Chibougamau on behalf of the Quebec Government and reported enthusiastically upon it. Subsequently, the late Dr. John E. Hardman made a lengthy and favorable report for private interests. Those reports received a good deal of publicity; and, as a consequence, a lot of attention was focused upon the newly discovered mineral riches of Chibougamau. But the difficulties of transportation were insurmountable—the district being located more than 100 miles from the head of Lake St. John, the nearest rail point in those days. Strenuous efforts were therefore made to induce the Quebec Government to build a railway into the region, which had some timber possibilities in addition to its reported mineral wealth. But the Quebec Government, with its customary caution, was not to be hurried into any such project, and it appointed a commission of various technical men to examine and to report on the economic possibilities of the district as a whole. The report, if favorable, was to form the basis for further consideration of the railway.

Unfortunately for those that had given not only of their time but of their money to the new area, "further consideration" was shelved owing to the fact that the commission's report was definitely unfavorable. It could see no good in the proposal, and damned it "bell, book, and candle." Therefore, quite naturally, interest in Chibougamau languished and died, and the district settled down to that condition which a famous statesman designated as "innocuous desuetude." The region that has since become famous was almost as remote in the popular mind as the North Pole. It might be remarked that the adverse report on Chibougamau was a heavy blow to Doctor Hardman. He was an engineer of wide reputation and a splendid gentleman of the old school. He had gone a long way in his recommendation regarding the district, and the commission's report hurt his pride. The hurt was deepened by the fact that he felt he was right. A few years before he died, interest in Chibougamau was revived, and once more it figured prominently in the news of the day. At that time this writer was associated with Doctor Hardman, who again and again declared his unshakable conviction that some day the district would be producing copper and gold. Now it looks as though his judgment is going to be vindicated, and with my knowledge of the man I do not know of one single thing that would have pleased him more. In fairness to the commission it must be stated, however, that it was faced with an economic as well as with a scientific problem, and that it probably acted quite correctly.

While the controversy over Chibougamau was agitating the legislators at Quebec, a venturesome soul, R. Renault by name, discovered gold at Lake Fortune which was in Quebec Province and near the Ontario boundary. That was in 1906. That strike was apparently attributable to the spreading out of prospectors from Larder Lake when that somewhat ill-starred area was in the throes of a rush. However, it did not make very much of an impression at the time, and the full significance of the continuation of the gold-bearing belt eastward from Kirkland Lake was not grasped because of the very simple fact that Kirkland Lake had not then been discovered. The Lake Fortune find was a somewhat isolated occurrence amid a veritable welter of more or less connected happenings, and it passed unheralded. It should be mentioned here that Lake Fortune has bobbed up in the news a number of times since 1906, but it has never made a mine, with which remark it may be dismissed from this chronicle. However, some note of it was necessary in order that the sequence of events in Quebec might be properly visualized.

Then came the discovery of Porcupine in 1909. Though some distance from Quebec, it had its effect upon that province. We have said that Porcupine completely altered the viewpoint of the men who were penetrating the North country. Gold became the siren luring adventurers ever farther from the beaten trails into the mists of far horizons; and as so often happens, because of some involved association of ideas, men seemed to think that the farther they went the more likely they were to find gold. It was a crystallization of the principle embodied in the old proverb, "Faraway pastures look greenest." Thus in 1910 we read in the papers of expeditions into Labrador and into Harricanaw, a district that seemed to be equally remote. Undoubtedly most people knew something about Labrador, whereas all the knowledge they had concerning Harricanaw was that it had a euphonious name smacking in some odd way of the old voyageurs.

Just exactly what took men into that area will probably never be written. It is likely that the Harricanaw River, crossing the right of way of the new Transcontinental Railway, attracted those northern adventurers just as a broad highway attracts men in the southlands. They wanted to see where it went. Anyhow, whatever it was, curiosity or planned design, J. J. Sullivan discovered gold in May of 1911 on the shores of Lake De-Montigny. In the same year the late Stanley Siscoe found the mine which now bears his name. There was a good deal of staking, and in 1912 the Greene-Stabell was uncovered by Robert Clark. Thus by the end of 1912 three groups of property, now producers, were discovered.

In spite of all this, nothing much was done. As we have remarked before, events were moving a little too rapidly to be properly digested. Porcupine was great,

EARLY-DAY SCENES

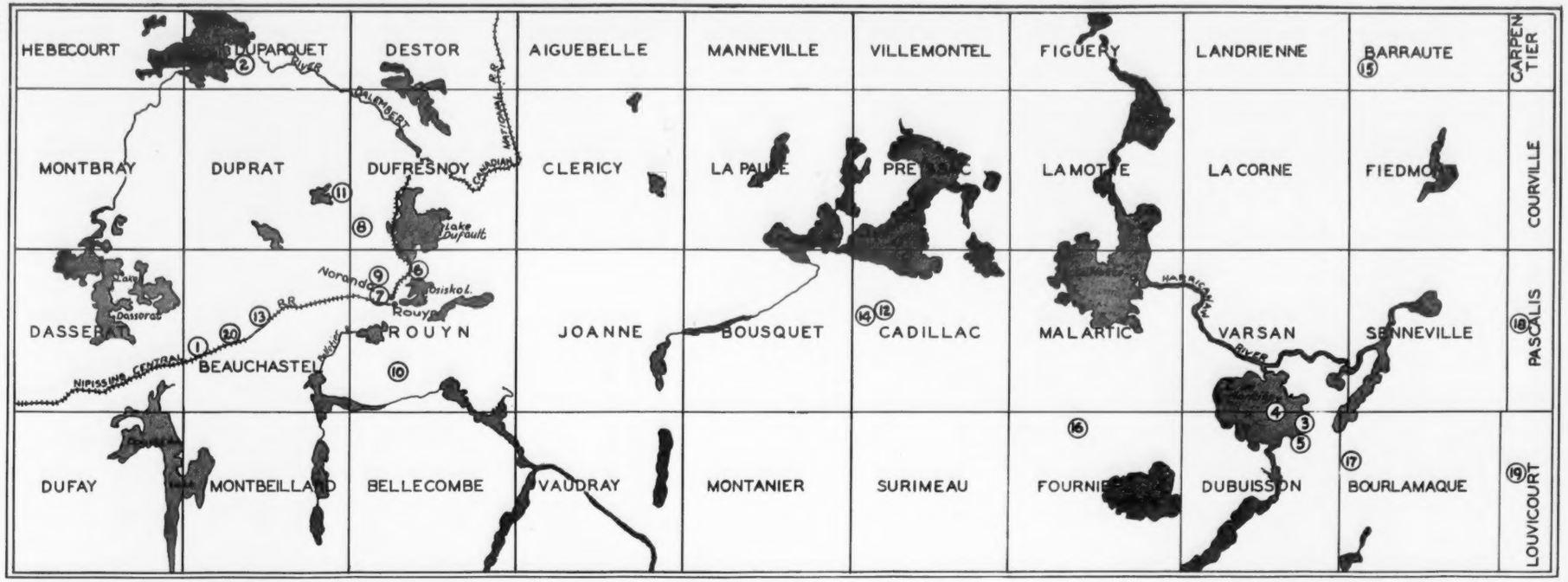
In 1911 Stanley Siscoe discovered the mine that now bears his name. In the picture at the left is the property when its development was at the stripping stage. Some of the richest ore ever produced in Canada came from the O'Brien-Cadillac Mine, which is shown just below and as it looked soon after work was started there. The first work done by the interests that developed the Noranda took place on the Chadbourne property, about two miles away, in 1923. The initial shaft site is seen at the bottom.

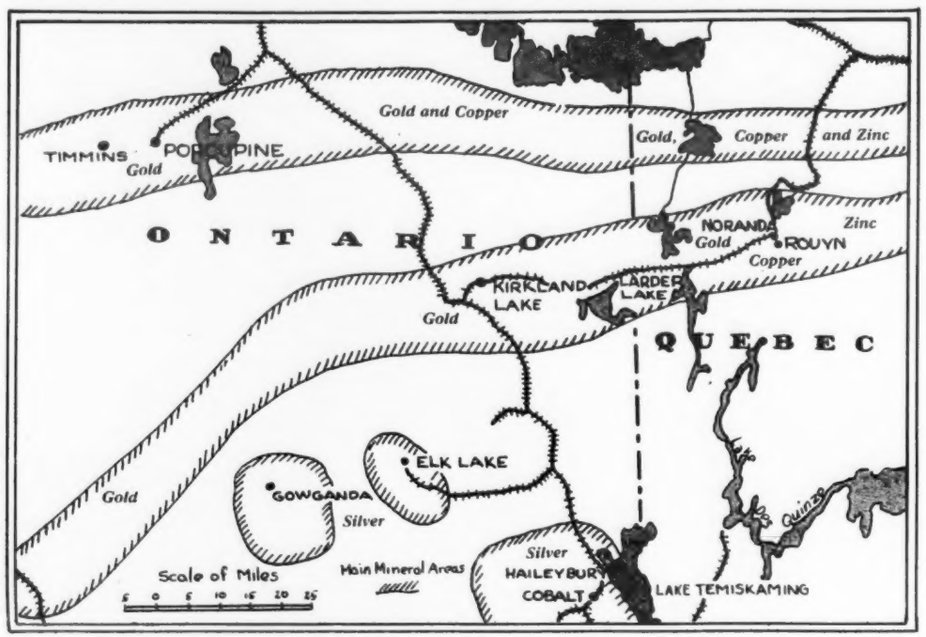
and it was one thing; Kirkland Lake was something else; and the properties around Lake DeMontigny were different again. We have seen how Kirkland Lake hung fire for years. Porcupine was spectacular, and these other places paled somewhat beside its magnificence. Furthermore, Lake DeMontigny, with its beautiful name so redolent with the elegance of French courts, appeared to be hopelessly remote. As a result, no one took much notice of it. Then the war came along with all its doubts and uncertainties, its strange braveries and its submergence of individual ambitions. New gold fields had to await exploration until the world worked off its strange madness. And wait they did. They waited so long that the world nearly forgot the discoveries on the picturesque shores of Lake DeMontigny; and the real development of northwestern Quebec sprang from other causes, which was something in the eternal irony of human events.

It is perhaps well at this point to examine a little more closely the position of what is generally known as the northwestern Quebec mining district in order properly to appreciate the following rather varied happenings. A glance at a map of Canada will show that part of the boundary between the provinces of Ontario and Quebec consists of a straight line extending north from Lake Timiskaming. Some 40 miles west of this line, in Ontario, lies the Kirkland field which, in its turn, is nearly 60 miles north of Cobalt. Almost due east of Kirkland Lake, and nearly on the Quebec border, lies Larder Lake.

The area we are contemplating runs almost straight east from the Ontario-Quebec boundary for a distance of about 80 miles and in line with Kirkland Lake and Larder Lake. Most of the production of the district has come from the townships of Beauchastel, Rouyn, Cadillac, Dubuisson, Bourlamaque and Duparquet. It will be noted from the accompanying sketch map that the townships of Dasserat, Beauchastel, Rouyn, Joanne, Bousquet, Cadillac, and Malartic extend eastward and in a straight line from the Ontario border. In Malartic Township the belt drops south to Fourniere, Dubuisson (where the early discoveries by Sullivan and Siscoe took place in 1911), Bourlamaque, and Louvicourt, which are also in a straight line. Most of the mines of importance are located along this belt of townships, excepting the Beattie Mine which is in Duparquet some twenty miles northwest of Rouyn. During 1910 John Beattie staked the claims that afterwards became the Beattie Gold Mine. He traversed the water route from the transcontinental railway down to Lake Abitibi and from thence to Lake Duparquet. His claims lay idle for more than fourteen years and did not come into production for more than twenty years, which is interesting but really aside from the fact that John Beattie was one of the earliest men to go into the district which has been so much in the public eye recently.

Returning to the belt of townships where the bulk of Quebec's producing gold mines are located, it should be noted that the 80-mile stretch lies, generally speaking, on the north side of the height of land and that the rivers run northward. Therefore those men that came in from the Transcontinental Railway traveled up the streams to the belt where most of the activity was centered. Later, prospecting and developing spread northward from that zone until now the northwestern Quebec mining district might almost be described as that tract bounded on the south by a line drawn from the south-





HOW CANADIAN MINING DEVELOPMENT SPREAD

The map at the left shows the relationship of the various mining districts that have been discussed to date in Mr. Rowe's series of articles, while the one above gives details of the northwestern Quebec area which is the subject of the accompanying text.

The general movement of mining development (but not of mineral discovery) was from Cobalt northward to Porcupine and Kirkland Lake. Next it turned eastward, crossing from Ontario into Quebec. Silver was the principal lure at Cobalt, but gold became the magnet as the camps farther north were opened. As we follow the metallic trail eastward, we find gold still occupying a prominent place, but with copper also attaining importance. Still farther to the east, zinc makes its appearance.

The numbers on the map above show the locations of properties which figure prominently in the text. The first actual find of mineral was on the Quebec side of Lake Timiskaming prior to 1750, but the region was then so remote from established settlements that little attention was paid to it. Next came the discovery by Peter McKenzie in 1904 at Chibougamau, which lies east of the region mapped. After a flurry of investigation, development of the section was held to be inadvisable by the Quebec Government mainly because it was difficult of access. Recently, with the advent of better transportation facilities, Chibougamau has shown promise of a prosperous future.

In 1906, R. Renault discovered gold at Lake Fortune (1). In 1910, John Beattie staked the claims that are now the Beattie Mine (2). A year later the Sullivan (3) and the Siscoe (4) were found, and in 1912 the Greene-Stabell (5) was located. Development was desultory, however, until Edmund Horne, after repeated trips to the region, discovered what is now the Noranda (6) in 1917. The company which was formed to develop it first worked the Chadbourne (7) with indifferent success, then finally turned to the Noranda and found rich copper ore that carried gold.

Other mines of importance, either as producers or as influences upon the development of the region, are: Amulet (8), Powell (9), Granada (10), Waite-Montgomery (11), O'Brien-Cadillac (12), Aldermac (13), Thompson-Cadillac (14), Venus (15), Malartic (16), Lamaque (17), Perron (18), Bussieres (19), and Arntfield (20).

LAMAQUE MINE

A picture of this gold mine taken at sundown. It is operated by the Teck-Hughes interests.

western extremity of Dasserat Township to the southeast corner of Louvicourt Township, on the north by the Transcontinental Railway, on the west by the Ontario-Quebec border, and on the east by a continuation of the east boundary of Louvicourt Township to the Transcontinental Railway. Such boundaries are very general in character because prospecting spread north of the railway (the Abana Mine—later Normetal—is north of the railway) as well as far east of the Louvicourt boundary. However, with the exception of Chibougamau and Opemiska Lake, there is not much to record in the latter direction. Naturally there has been a good deal of prospecting south of the line we have traced, and there have been some results; but for the purposes of this history we can retain the boundaries we have just outlined; and it requires only a glance to see that they embrace a large area. All of which brings us to some consideration of the activities of Edmund Horne, who found the Horne Mine which has become famous and which is more generally known as the Noranda.

Edmund Horne was an experienced prospector. He was born in Nova Scotia and worked in the gold mines of his native province as a youth. At an early age he left and wandered through parts of the United States and British Columbia. He finally drifted across Canada to northern Ontario, and then began a tale of persistence which, in its peculiarities, is hard to beat in the annals of mining. During 1911 he made a trip into northwestern Quebec. It was one of those transitory trips which are so characteristic of the true, born prospector; and at this date it seems to have had no particular object except the assuaging of that insatiable curiosity of the real adventurer. It is probable, however, that rumor had something to do with it, for there were many stories coming out of Quebec at the time; and there are men who claim to have seen samples originating from the general area where Horne made his discoveries as long ago as 1910. On his way back Edmund Horne camped on the shores of Osisko Lake (then Tremoy Lake) in the vicinity of the spot where he later made his famous strike.

He apparently did no prospecting, but noted some rusty gossan. It must be remembered that in those days gossans did not hold any particular significance for the prospectors of northern Ontario; and, like all the others, the mind of Edmund Horne was full of visions of gold in quartz veins. Therefore he broke his camp and proceeded on to northern Ontario; but some latent association of ideas remained indelibly fixed in his memory, for in 1914 he was back. This time he prospected, but did not find anything, and once more he left. Osisko Lake (still called Tremoy), however, was a lodestone so far as Ed Horne was concerned, and the interest it aroused in him simply refused to be downed, so in 1917 we find him there again picking and panning. On that occasion he got gold values, but his assays were disappointingly low—so low, in fact, that the majority of people would have shrugged their shoulders and most certainly have dismissed the area with possibly lingering regrets. Remember, gold was the only thing that then concerned Horne, for those were still the days when values of $5 to the ton or under were not considered to be of commercial importance.

Edmund Horne, however, did not dismiss Osisko Lake with lingering or any other regrets. In truth, he did not dismiss it at all, but kept hammering away looking for money to help him explore more thoroughly the region which had become an obsession with him. He might have continued his search for many a long period but for the fact that Kirkland Lake was then beginning to emerge from its swaddling clothes and to startle the world—a fact that had its effect upon the destiny of northwestern Quebec. People with money were learning that there were possibilities in districts that did not display bonanza qualities at surface. In short, Canada was learning a great deal about itself. Finally, in 1920 to be exact, Edmund Horne succeeded in forming a syndicate of New Liskeard men. It was called Tremoy Lake Shore Mines Syndicate.

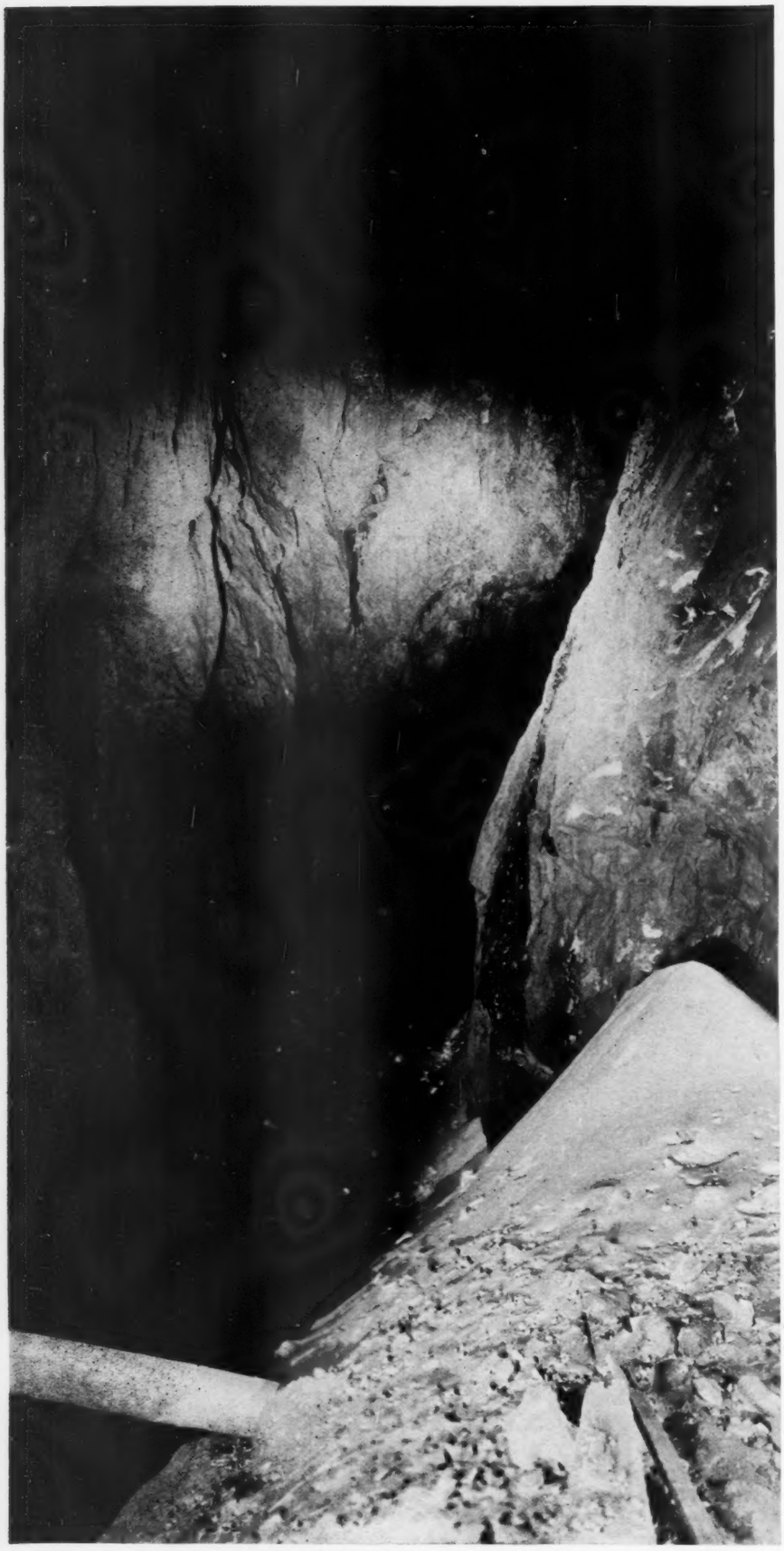
With funds available, Edmund Horne and Ed Miller started for Klock's Farm at the head of Lake Timiskaming, and canoed up Des Quinze Lake into Opasatika Lake, up Lonely River, Long Lake, and thence to Island Lake (not to be confused with Island Lake, Manitoba, of later fame), where they prospected for a few days before turning back to Opasatika Lake and from that point following the Pelletier Lake route to Tremoy Lake. There they staked 70 acres; and it is interesting to note that this first staking covered most of the ground in which the famous ore bodies of Noranda were later discovered. In 1921 more work was done, but most of it was disappointing, and it was not until late that year that some channel samples showed values running $30 to $40 per ton. Thereupon Horne staked another 200 acres; and early in 1922, just to be sure about things, he staked still another 400 acres.

The high assays obtained by Horne in 1921 eventually turned out to be freaks; but they were sufficient to fire the spark of imagination, and a picturesque and lurid rush ensued with the result that the region was staked solid in a short time. Most of this staking was blind. In fact, a great deal of it was done while the country was under a heavy blanket of snow. Taken generally, the district was heavily wooded—rock outcrops being less frequent than in some other sections of the north. The overburden is heavy in the flat and low-lying parts of the land; and there were many claims staked upon which rock was never found.

It is worth mentioning here that the men who were in the region were still gold-minded, and the precious metal was the only thing in their thoughts. Thus, as 1922 opened, work was going forward in the

ALDERMAC MINE

Discovered in 1925, this property was named for W. P. Alderson and A. A. MacKay who developed it into a producer of iron pyrites and copper. Because of the low price of base metals, the Aldermac has not been operating recently.



A RICH NORANDA STOPE

More than 500,000 tons of high-grade ore was taken from this opening on the 400-foot level. The stope extends to the surface, and the white cone in the foreground is snow.

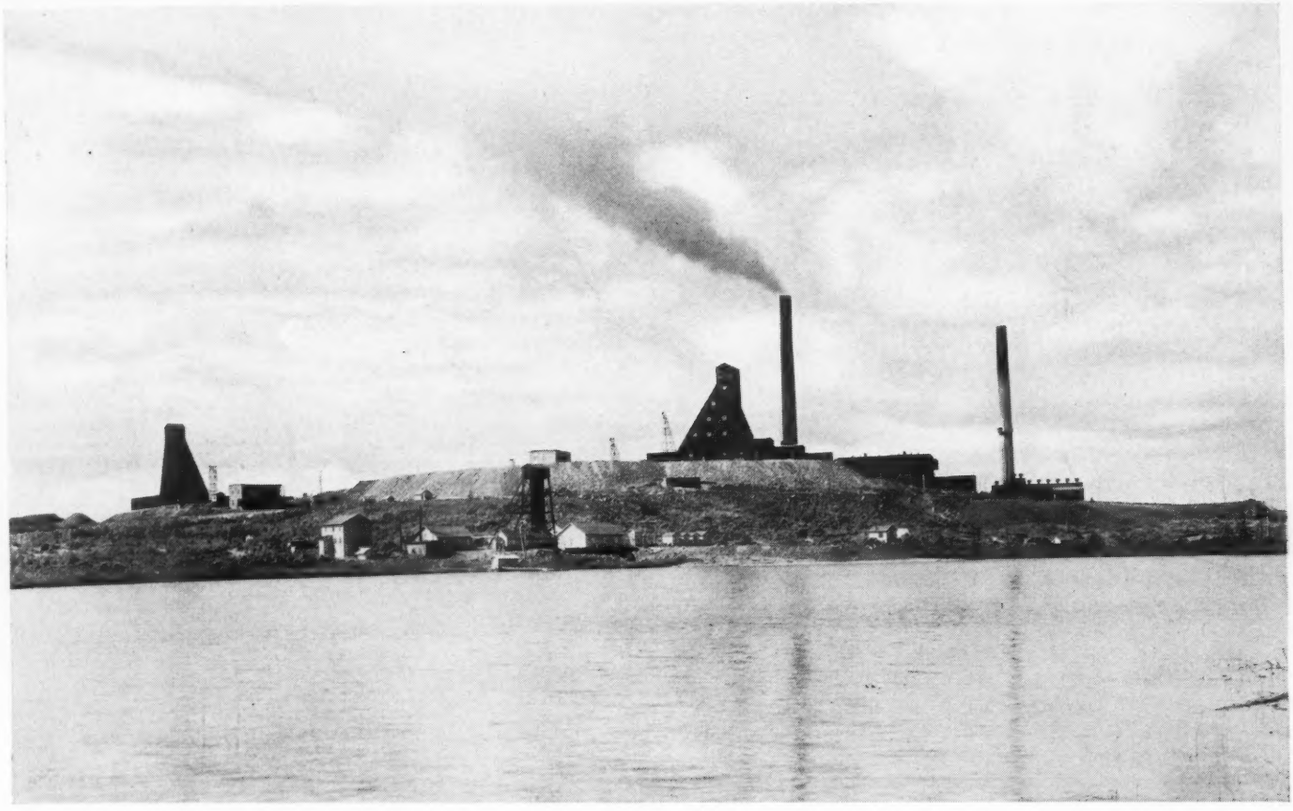
vicinity of Lake DeMontigny on properties which had been known for years, while some miles west, at Osisko Lake, there was a good deal of milling around without anyone yet having any very clear conception of what it was all about.

Meanwhile certain matters were transpiring which were to have a very far-reaching effect upon northwestern Quebec. One of these was the formation of a syndicate for the purpose of exploring promising mineral areas, acquiring claims, and developing mining properties. The leading spirits of this enterprise were S. C. Thompson and H. W. Chadbourne. They formed what was known as the Thompson-Chadbourne Syndicate, which took over the Tremoy Lake Shore properties discovered by Horne and Miller. The latter syndicate consisted of thirteen members, including Horne and Miller. The arrangement entered into by the two latter was that their interest in the syndicate would be two-fifths, and that the remaining three-fifths would be divided among the eleven other members. In return for the two-fifths interest, Horne and Miller were to turn over to the syndicate any properties they might locate, while the other members were to put up whatever funds were required. The cash advances of the eleven finally amounted to about $5,000, while Horne and Miller turned in the properties found by them. This completed the contributions made by all concerned.

When the Thompson-Chadbourne Syndicate acquired the properties of the Tremoy Lake Shore Syndicate, certain cash payments and a 10 per cent interest in an operating company were the terms of the transfer. Early in 1926 the marketable value of the Tremoy Lake Shore Syndicate was $1,800,000, based on the values of syndicate units as quoted on exchanges. This is an outstanding example of the fruits to be gathered from mining enterprises; but we hasten to add that the fruits were not gathered quickly, for there were many vicissitudes before the units of the Tremoy Lake Shore Syndicate reached an aggregate value of $1,800,000.

In the first place the Thompson-Chadbourne Syndicate did not find the low values of the Horne showings very encouraging, and attention was concentrated on a gold-bearing rhyolite breccia on a property known as the Chadbourne and lying about two miles to the northwest. A shaft was sunk there to a depth of 150 feet and a good deal of underground work was done; but the findings were definitely disappointing. In December of 1922 Noranda Mines, Limited, was formed with James Y. Murdoch as president. It took over all the holdings of the syndicate and continued active work on the gold properties referred to.

Finally, in 1923, results at the Chadbourne became so discouraging that in August a diamond drill was moved over to the properties discovered by Horne. The first hole was drilled from a surface trench



NORANDA MINE IN 1931

Courtesy, Geological Survey of Canada

A view from Osisko Lake prior to the building of the concentrator and smelter which are now included in the property. This mine was originally known as the Horne, after its discoverer, Edmund Horne.

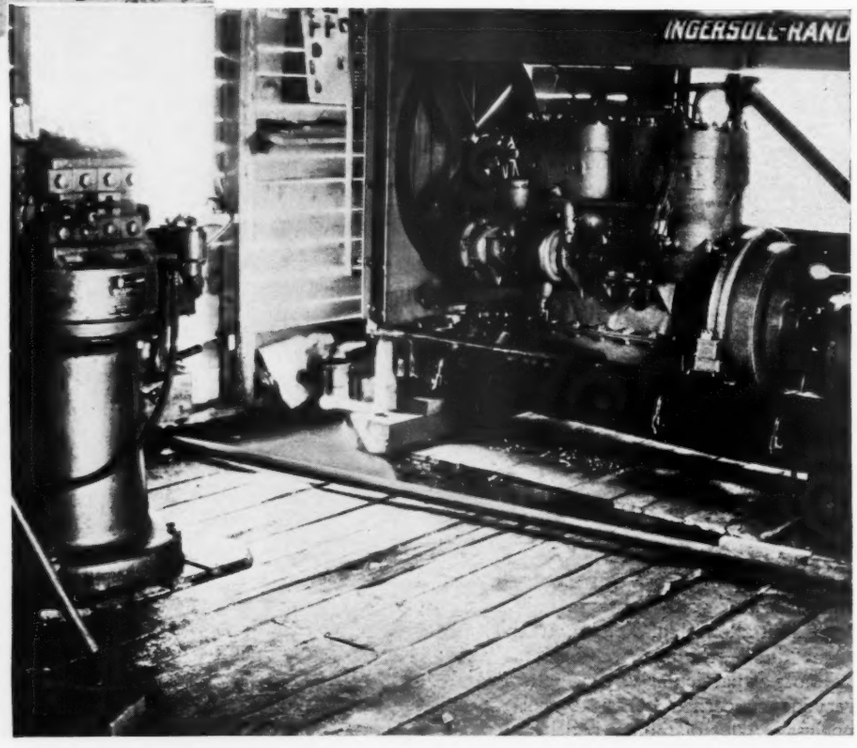
which showed gold values of about $7 throughout a length of 30 feet; but the hole was a "dud"—the core was barren. This was not a particularly good start, and everyone concerned began to feel rather hopeless. A lot of money had been spent on the Chadbourne, and now the Horne property began to look like a failure. After some deliberation the drill was shifted about 1,000 feet east, where a trench had disclosed massive pyrrhotite carrying some gold. The writer has talked with one of the drillers on this job and gathered that the drill crew, with that delightful disregard for technical knowledge which is so characteristic of their kind, laid bets that this hole also would be a "dud." For 13 feet it looked as though they might be right in their pessimistic forecasts, but at that point the drill entered massive sulphide and continued in it for 130 feet. The first 49 feet was practically solid pyrrhotite containing an average of $6.58 in gold and 0.92 per cent copper, which was not considered to be so good as gold ores even as recently as twelve years ago. But the next 81 feet of core showed a replacement of pyrrhotite with chalcopyrite, and assayed $5.42 gold per ton and 8.45 per cent copper.

It may be remembered that around that date the world was entering that revered and distant period that has since become known as "the period of prosperity." Copper prices were going up. Well-nigh overnight the conception of the Horne property changed, and it turned from a gold to a copper mine. In almost the same space of time prospecting for copper became the fashion. There is an intriguing study in psychology in that quick twist of viewpoint. In many ways it was comparable with what took place when Porcupine was discovered. We have remarked that up until then silver filled the minds of men; but the sight of the gold-seamed hummocks of quartz at Porcupine started men feverishly searching for that precious metal. That quest continued in the North for fourteen years, practically to the exclusion of everything else; and then the copper-filled cores of the diamond drills working on the Horne property initiated the hunt for copper and ushered in an orgy of wildcat promotion.

The real development of northwestern Quebec began at that time, and it differed somewhat from that of the other fields we have traced so far in that it was spread over a large area: it was not concentrated within a comparatively restricted radius. Any contemplation of that development would be quite incomplete without some reference to the events that transpired after Horne and Miller got high assays from channel samples in their prospecting trenches. We have seen how the news of those assays started a stampede into the area, a stampede that continued through the winter of 1922-23 and resulted in a tremendous amount of staking. Thus when the open season of 1923 began, the district presented a scene of great activity which crystallized the difficulties of transportation.

The general region around Rouyn—the name of the township in which the Horne discoveries were made—could be reached from the recently completed Transcontinental Railway line to the North, as well as by water and overland travel from the terminus of the Nipissing Central Railway at Larder Lake. It should be mentioned parenthetically that the Nipissing Central was the name of the Ontario-Government-owned railway from Swastika to Kirkland Lake and eastern points. This is brought out because of a pretty controversy that raged later on about its ambitions, a subject that will be touched upon subsequently. Returning, however, to the routes into Rouyn, neither of them was ideal for general travel even though both presented no great hardships to experienced bush travelers.

It was these conditions that caused certain far-seeing and quite courageous souls to conceive and to put into effect the first real commercial air service in Canada. During 1923 the Laurentide Air Service,



PORTABLE AIR PLANTS

Before portable compressors became standard equipment, the hauling in and setting up of boilers and steam-driven compressors constituted herculean tasks. The portable unit made it possible quickly and easily to set up compact compressor and steel-sharpening shops, such as that shown below. Even the moving of this lighter equipment presented problems, as is attested to by the view at the left. In this instance, the bridge would not bear the weight of both the compressor and the tractor that was hauling it, so the former was drawn across the structure by a 12-man team.

under the management of Mr. Wiltshire and Colonel Scott-Williams, started regular flights to the northwestern Quebec area from Angliers, the terminus of the Mattawa branch of the Canadian Pacific Railway on the Quebec side of Lake Timiskaming. Two planes were maintained, one of which was piloted by John Caldwell who crashed to his death near Montreal a few years ago. Looking back now it is not so easy to comprehend clearly the physical and financial chances those men took. Commercial air travel is almost commonplace today, and the aeroplane is a definitely established arm of the mining industry. But twelve years ago, those pilots were pioneering and venturing into a realm of human endeavor that was as completely unknown so far as this country is concerned as the farthest fringe of civilization that was being probed by the prospectors of that day.

It is one of the little ironies of national events that, in the light of later spectacular aerial achievements, the first Canadian enterprise in the field of commercial aviation should have been almost forgotten. Yet such is the fact; and it gives this writer a great deal of pleasure to bring it back to attention, and assign to it its proper place in the history of pioneer flying in Canada where aerial navigation has reached such a stage of efficiency that we are rightfully proud of it.

The record of those early aviators is a brave one. The service was operated by the originators of it during 1923 and 1924, and in the whole time they did not lose a passenger nor a pound of freight. The first piece of freight transported by plane into the Rouyn area was a 350-pound hoisting cable sent by Nipissing Mines to the Powell property north of the Horne claims. During 1924 the planes carried 425 passengers, 8,599 pounds of baggage, 55,385 pounds of freight, and 780 pounds of mail, the latter being the first mail to be thus transported in Canada.

These are bald figures and equally bald facts. Behind them lies a brand of skill that we cannot surpass even today, not to mention ingenuity and courage of the highest order. There will be many who read these lines who will remember flying into Rouyn, and who will look back with a pleasant thought and a little wistfulness upon days when somehow the world seemed much younger than today. They will remember how the plane was loaded with all the gear needed by men engaged in pioneering and opening up new country: how there were cans of lamp oil, bars of steel, cases of canned stuff, rolls of blankets, portable stoves, boxes of tools—in fact, every conceivable thing required by men who have work to do. And there seemed to be a great comradeship between passengers and pilots: a willingness on the part of the former to take the rough with the smooth. If there were forced landings, and there were many, it was all part of the game, and everyone put his best face on whatever chance brought him.

Obviously it did not take prospectors and engineers long to grasp the mobility of the new arm; and it was only a little while after Laurentide Air Service started that its planes were being chartered to drop on to faraway and unknown lakes. Men quickly learned how the plane annihilated distance and overcame the great devastating factor of time, which has always been such a terrific obstacle in a country of great distances and short open seasons. They have never forgotten that lesson; and it can be said without fear of contradiction that the aeroplane has brought the Canadian North almost to the back doors of cities and has advanced the development of that part of the Dominion at least twenty years.

In a succeeding chapter of this history some account will be given of the contribution the aeroplane has made to the opening up of the newer gold districts of Ontario and Manitoba; but we may be forgiven here for giving so much space to that first venture into commercial aviation twelve years ago that was the beginning of it all. It was a splendid effort.

This is the seventh of a series of articles by Mr. Rowe. The eighth will appear in the December issue.

Detachable Drill Bits Reduce Mine Costs

Improvement in Practice Results from Change to "Jackbits" at Mascot, Tenn.

Harley A. Coy*

THE following article is a reprint of a paper which was read by Mr. Coy at the Metal Mining Convention and Exposition of the American Mining Congress at Chicago on September 24. Its complete title was: *Experience in the Use of Detachable Drill Bits at the Mines of The American Zinc Company of Tennessee at Mascot, Tenn.* It is reproduced here, with the author's permission, because of the present widespread interest in the possibility of obtaining greater drilling economy by the use of these convenient bits.

THE ore-bearing horizon at Mascot is dolomitic limestone. The metallic mineral is zinc sulphide and occurs principally as completely filled veinlets or seams in limestone and in association with secondary dolomite. Such average Mascot ore presents no particular drilling difficulties; but occasional chert beds or chert nodules are present, and these, when encountered, retard drilling progress and increase the wear on bits.

Mine advancements made there from year to year have increased transportation distances from working places to haulage lines, and the additional time required to go to and from working places has reduced actual drilling time, thereby giving added importance to better drilling performance.

All stoping and drifting is under contract. Each stope contractor is himself a drill operator. His returns are based upon the tonnage obtained from his working place. In addition to operating his machine he is required to lay air lines, to set up his equipment, and to keep the roof of his working place in safe condition. The production from his stope—and, therefore, his return—is dependent upon the amount of drilling he may be able to do after these duties have been performed. The drilling time lost in the transportation of steel also results in a loss of production and, accordingly, reduces the contractor's return.

The heading-and-bench method is followed in mining. Stoping drills are of the 3-inch-diameter type. They are mounted for heading work: for vertical drilling on benches they are removed from the slides. Machines of the 3½-inch type are used in drifting and in crosscutting.

The blacksmith shop is centrally located on the main haulage level near the shaft. Its equipment consists of one No. 5 Ingersoll-Rand steel sharpener, of an oil-fired furnace, and of tempering vats. Adjoining the blacksmith shop is the detachable-bit room in which is located an Ingersoll-Rand bit grinder, bins for both dull and sharpened bits, and a rack for drill rods. Bit carriers, arranged in groups of two, hang on brackets on the walls of this room. Each group bears a drill operator's number, and this number also appears on the wall above the position of that pair.

All bits and drill rods are issued from this room by the blacksmith, and are carried by the men to their working places. Prior to the use of detachable bits, drill steel was distributed by locomotives to the men at points along haulageways and carried by them from those points to their working places. In a few instances, in the case of particularly inaccessible points, drill steel was transported from haulageways by mechanical means.

The drill steel that now serves for rods for detachable bits is of two types: 1¼-inch hollow round lugged steel in stoping and development work, and 1⅛-inch hollow round in short lengths for blocking, this having been substituted for the ⅞-inch hollow hexagon steel formerly used. A small quantity of ⅞-inch solid hexagon steel is employed solely in raise work where the stoping machines, being hand rotated, are not suitable for use in connection with detachable bits.

Upon the adoption of detachable bits, 2-foot drill-rod changes were made standard for all types of drilling. Recently, however, this length has been increased to 3 feet in

*Superintendent of Mines, The American Zinc Company of Tennessee.

THE "JACKBIT" ROOM

In this underground shop all bits are resharpened and placed in carriers, ready for the drill operators at the start of each shift.

order to reduce the number of rods and bits in service. Rods more than 10 feet in length are not permitted, except for special purposes such as prospecting, roof work, or slabbing.

The forged type of Carr bit had been in use at Mascot for many years, it having been demonstrated that it had a greater penetration speed per minute than the forged type of cross bit. However, in adopting the detachable bit, the cross-type bit was selected because of its greater safety and capability to hold gauge. The Carr bit, it had been found, had a tendency to wedge when a fracture zone, or ground of unequal hardness, was encountered. This tendency had been known to twist the machine to such an extent as to throw the operator from the bench.

Early in 1933, three makes of detachable bits were tested at a point in the mine where the rock formation appeared to be uniform and where a constant air pressure could be maintained. Included in the test were bits of the cross, Carr, and 6-point types, with both center and side holes. The usual procedure for determining penetration speed per minute and cutting-edge and gauge wear was followed. Data were obtained on the maximum footage necessary to run each type of bit to destruction, as well as on steel breakage and the effect of the various tempers on both rods and bits.

Following this preliminary test, bits of the three makes were tried out for a period under actual operating conditions, during which time 22 stope machines and four development machines were used. These various tests resulted in changing the bits for all stope, development, and blocking machines to the standard 1-inch cross-type Ingersoll-Rand detachable "Jackbit." A gauge variation of $\frac{1}{8}$ inch per change was adopted, with $2\frac{1}{8}$-inch starters being followed consecutively by bits of 2-, $1\frac{7}{8}$-, $1\frac{3}{4}$-, $1\frac{5}{8}$-, and (special) $1\frac{1}{2}$-inch gauges.

During the experimental period the drill rods had been threaded by lathe, but this so weakened them as to cause a breakage of approximately 30 rods per drilling shift. This difficulty was overcome by the development by Ingersoll-Rand Company of a forging die for the drill sharpener by means of which the threads are now forged on to the rods. The forging of the threads, together with added experience in tempering, resulted in reducing the average breakage to $6\frac{1}{2}$ rods per drilling shift.

DETAILS OF CARRIERS

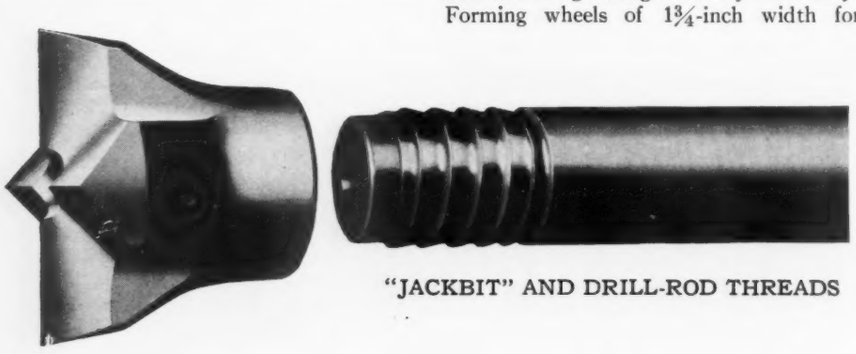
Two metal containers for "Jackbits" are assigned to each drill runner and are hung in numbered positions on the wall. Each man takes out a carrier full of sharp bits at the start of the shift and is accountable for its return at the shift end. Between shifts, the carrier remaining in the shop is filled with resharpened bits. The carriers shown are those used by stope machine men. Those supplied the development machine men have places for ten bits.

During the test period the forming and gauging of detachable bits were done by a standard bench grinder. This proved unsatisfactory, and an Ingersoll-Rand Type J-2 electric-driven bit grinder, with a 12x1¾x1¼-inch forming wheel and a 12x1½x1¼-inch gauging wheel, has since been used. A type 36-WO Borolon wheel, manufactured by the Abrasive Company, was adopted. This installation bettered the grinding efficiency materially. Forming wheels of $1\frac{3}{4}$-inch width for larger gauge bits and $1\frac{1}{4}$-inch wheels for smaller bits are in use at present.

Each machine man is assigned two bit carriers, those for stope use holding six bits and those for development work holding ten bits. One carrier filled with sharpened bits is supplied at the beginning of the shift, an arrangement which allows one of each pair of carriers to remain in the shop each day for refilling. At the end of the shift each machine man is required to account for all bits received by him when the shift started. All lost or broken bits must be reported to the foreman, who authorizes the blacksmith to substitute others for them.

Ordinarily five bits are sufficient for a machine shift in stope work. The sixth bit —usually, but not always, of 2-inch gauge —is furnished as a spare. Where two machine men are working in the same stope, an interchange of drill rods or bits is permissible, and this arrangement frequently prevents loss of time.

Owing to the accumulation of resharpened bits, the only new bits issued in



"JACKBIT" AND DRILL-ROD THREADS

SHARPENING BITS

By means of this Type J-2 grinder, bits are successively reground until they have been reduced, ⅛ inch at a time, through all gauges from 2⅛ to 1⅝ or 1½ inches. They are usually retempered after the third grinding. This procedure makes it necessary to buy bits of only the starting size, 2⅛-inch gauge.

actual practice are of the starter-gauge size, 2⅛ inches. When unusual gauge wear but not great loss in stock occurs, as when drilling chert, the bits are upset on the drill sharpener by means of a special die and bit holder developed in our local shop. All upset bits are ground, gauged, and tempered.

The average temper depth in a new bit is approximately ⅜ inch. After this hardness has been lost, bits are retempered. This usually follows the third grinding. For tempering, the bits are heated slowly to about 1,400°F., and are then placed in ⅜ inch to ½ inch depth of water, where they remain until cold. The depth of quenching is determined by the amount of stock in the bit.

"Jackbits" are carried in stock by Ingersoll-Rand Company at their warehouse in Knoxville. Transportation from the warehouse to Mascot, about twelve miles, is by truck, and all charges in that connection are included in the following costs.

During the first five months of 1935, a total of 4,824 new 2⅛-inch bits was purchased at an average cost to the mine of $0.2536 per bit. During the same period 27,312 bits were reground—including 966 bits that were upset, or an average of 5.66 bits reground per new bit purchased. During that 5-month period the average bit purchased drilled 36.81 feet, at a per foot cost of $0.00689, before it was discarded.

In the grinding of the 27,312 bits, 32 forming wheels were used, or one wheel per 853.5 bits ground, at a cost of $0.00811 per bit. When wear has reduced the diameter of the forming wheel to such a point that grinding speed is retarded, the wheel is transferred to the gauging side of the grinder. During the period mentioned, in addition to the old forming wheels so used, ten new gauging wheels were put into service, the wheel cost for the combined forming and gauging of the 27,312 bits being $0.01064 per bit.

For tempering, the thread ends of the drill rods are heated from 1,550° to 1,600°F. They are then submerged in 8 inches of fish oil for 30 seconds, after which they are cooled in about ⅜ inch of water. Experience has lessened materially the breakage of thread ends during the removal of bits from them.

The following tabulation compares the average cost experience with drill steel with forged type Carr bits over a 5-year period with that of detachable cross bits over a 5-month period in 1935. A saving of $0.00648 per foot drilled in favor of detachable bits is indicated, being, in this instance, the equivalent of a yearly saving of $2,761.56.

A comparison of the footage drilled per machine shift during the 5-month period in 1935 with that of the 4-year period immediately preceding, indicates an increase of 4.25 feet since the installation of the detachable bits. Physical and operating conditions corresponded closely during the two periods. The increased footage is attributable in part to several conditions, among which are included: less time and effort expended by the drill operator in transporting steel from haulageways to drilling faces; elimination of a tendency on the part of the machine man, because of the greater effort involved in carrying forged steel, to continue its use after efficient cutting and gauge conditions have passed, a practice that results in excessive drill repair cost and increased air consumption; and the general but more or less intangible betterments, including safety, that accompany the handling of less weight of material.

The change from forged bits to detachable bits at the Mascot operation is looked upon as a decided improvement in practice, and it is expected that with added experience further betterments in cost will result.

COMPARATIVE COSTS OF MINING WITH FIXED AND DETACHABLE BITS

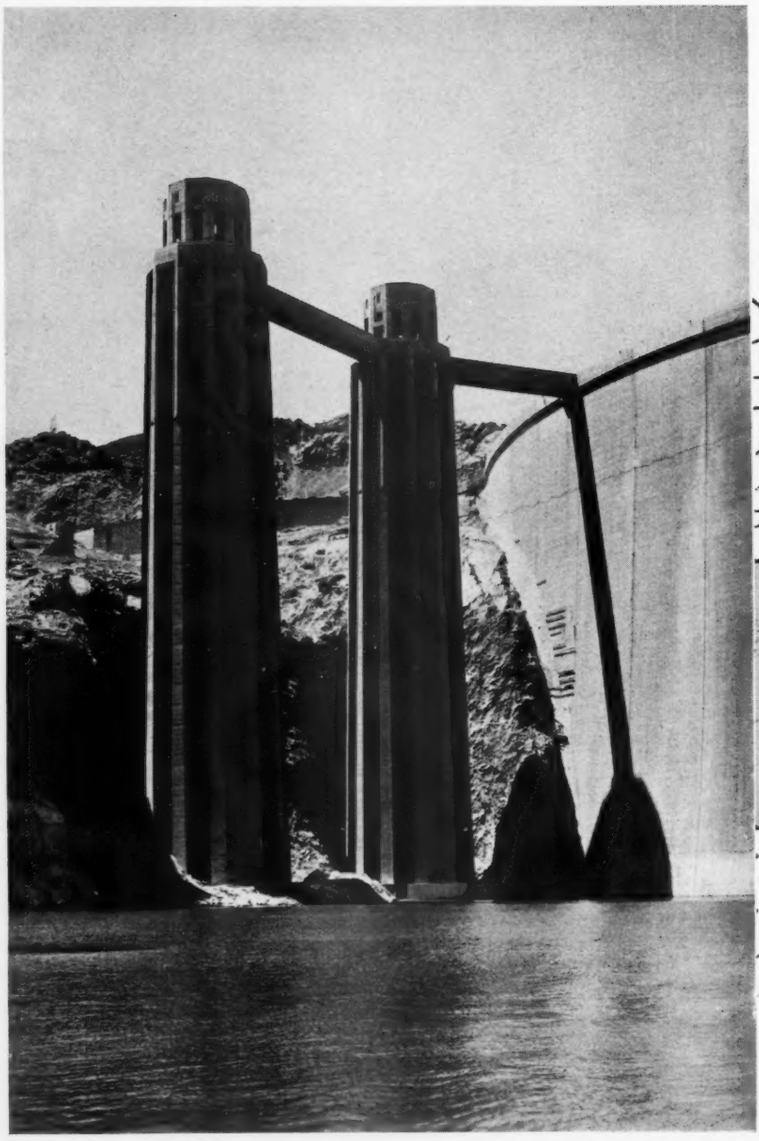
	BITS FORGED ON STEELS FIVE YEARS' EXPERIENCE (1927—1931)	DETACHABLE BITS FIVE MONTHS' EXPERIENCE (FIRST HALF 1935)
Total feet drilled	1,738,171	177,567
	PER FOOT OF HOLE DRILLED	PER FOOT OF HOLE DRILLED
Steel sharpening (labor)	$0.00809	$0.00635
Drill steel	0.00541	0.00273
Fuel (oil furnace)	0.00125	0.00031
Oil and cyanide	0.00008	0.00008
Steel sharpener (repairs)	0.00143	0.00145
Shop tools and grinding wheels	0.00023	0.00173
Detachable bits	.....	0.00689
Steel transportation (mine)	0.00255	.....
Steel loss	0.00027	0.00007
Drill repairs	0.00933	0.00530
Compressed air (drilling)	0.06345	0.05943
Miscellaneous	0.00072	0.00199
TOTAL	$0.09281	$0.08633

Construction of the Boulder Dam*

How the $35,000,000 Power Plant Will Appear When Completely Equipped

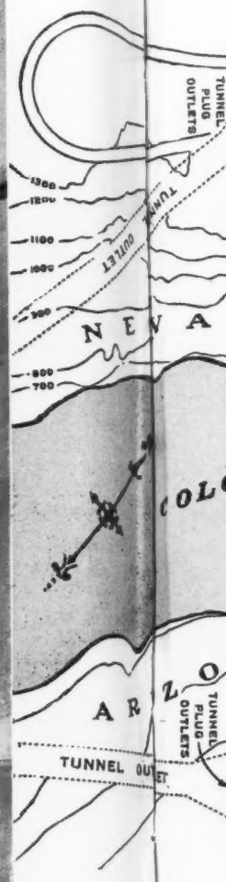
Wesley R. Nelson†

All illustrations were furnished by the U. S. Bureau of Reclamation.



INTAKE TOWERS

Through cylindrical gates in these 390-foot-high reinforced-concrete structures, two of which are located on each side of the river, water will be taken from the reservoir and directed through steel-pipe-lined tunnels to the turbines. Each tower has an average diameter of 75 feet. When this picture was taken, July, 1935, the reservoir surface was at elevation 884, or 10 feet below the base level of the towers which are built upon shelves in the canyon walls.



THE power that through the ages has worn the mile-deep chasm of Grand Canyon, cut black gorges through mountain ranges, and thrown a delta entirely across the Gulf of California to form the Imperial Valley, will soon be directed to more useful pursuits when the generators in the Boulder power plant commence their hum of creation and conservation.

Many visitors to Black Canyon are not particularly impressed by the size of the power-house structure as viewed from the canyon rim, for its nineteen stories of height and four acres of roof are dwarfed by the encompassing canyon walls and by the dam that rises immediately upstream. Yet more difficult is it to realize that in that relatively small space enough electricity will be produced at plant capacity to furnish each and every family in the United States with light from a 40-watt lamp, or sufficient energy to supply all the domestic light and power needed by the 8,500,000 inhabitants of the Colorado River Basin states.

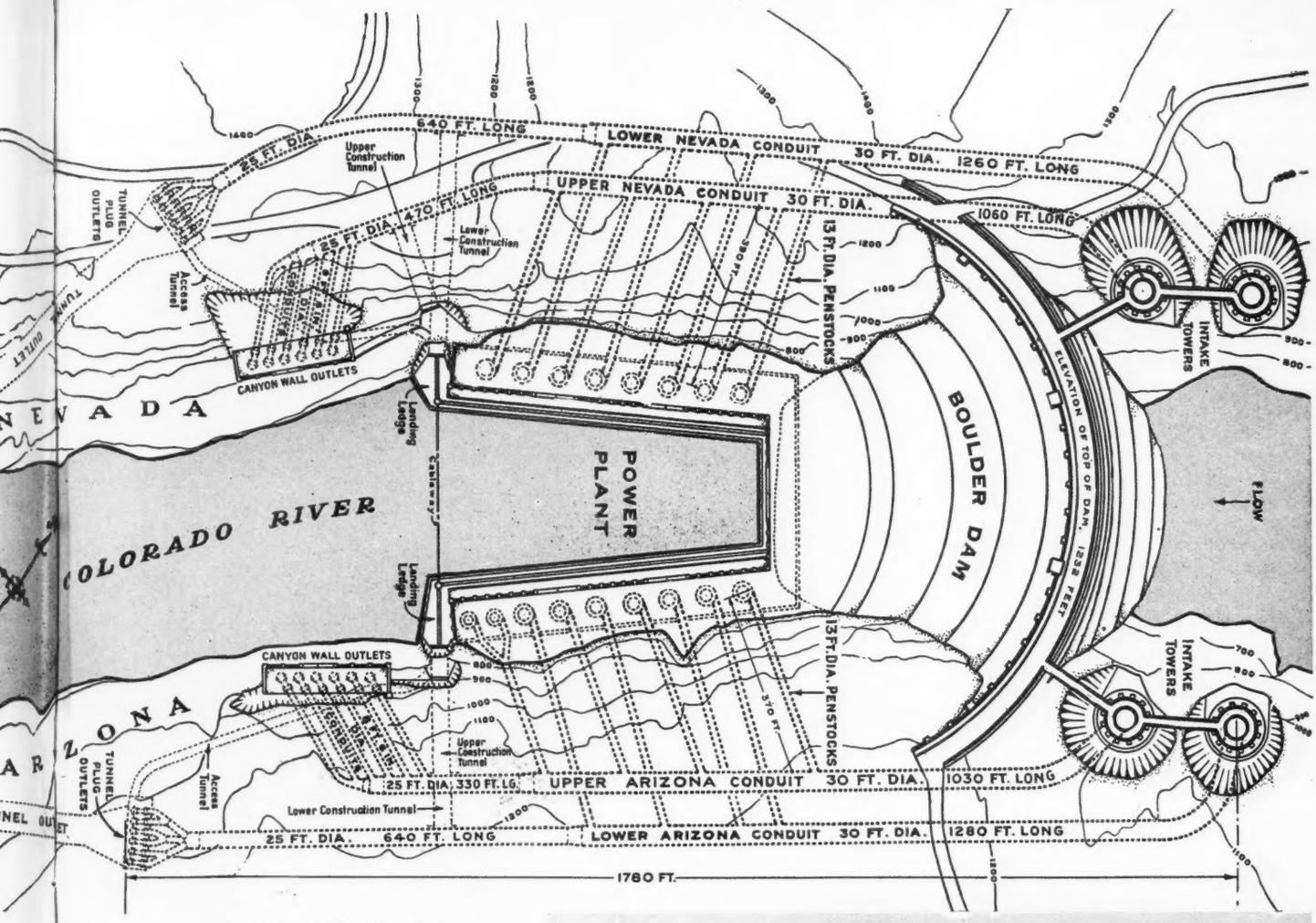
The generation of electrical energy at Boulder Dam is mentioned last among the purposes of the project as set forth in the Congressional Act that authorized construction. Nevertheless, without the income from that source the building of the dam and its outlet works would have been economically infeasible, because the tillers of the lands that are benefited by flood control, silt control, and water storage could not afford to foot the bill. By the present arrangements, through contracts for power signed before work was initiated, the entire $108,800,000 for construction and an additional $11,200,000 of interest charges will be repaid the Government by 1985.

The site chosen for the U-shaped power house is immediately downstream from the dam, one wing nestling at the foot of each canyon wall, and the central part, connecting the two wings, resting on the downstream toe of the dam. Measured by chain and level rod in boresome feet, each wing is approximately 650 feet long next to the cliff and 150 feet wide at the generator-floor level, while the central section is 400 feet around at the roof and dam intersection and rises 229 feet above the lowest foundation concrete, or 154 feet above the tailrace low-water surface. Using more familiar yardsticks—the distance around the U is that of five ordinary residence blocks, while the roof parapet is nineteen stories above the lowest concrete and twelve stories above the tailrace. The roof has an area equivalent to that of two city blocks, and beneath it are about ten acres of floors.

Six Companies Inc. has built the power house from materials furnished by the

*Twenty-first of a series of articles on the Colorado River and the building of the Boulder (formerly Hoover) Dam.

†Associate Engineer, U. S. Bureau of Reclamation, Boulder Canyon Project.



PLAN OF OPERATION

The drawing above shows how the water which enters the intake towers will be carried through the canyon walls and either directed to the turbines of the power house or discharged into the river downstream from the dam through the outlet works. The diameters given in connection with the various tunnels refer to the steel pipes which are being installed within them by The Babcock & Wilcox Company.

At the right is a composite picture made by imposing an artist's drawing upon a photograph in order to show how Boulder Dam will appear when the reservoir is filled and the power house is in operation.

Government and has set up the cranes; but most of the 80,000,000 pounds of machinery is being placed by the forces of the U. S. Bureau of Reclamation. The larger generators and the automatic elevators in the dam and power plant are being installed by the manufacturers.

Although in its general details the structure was erected in a manner similar to city buildings, its construction was unique in that the materials were usually lowered from 600 feet above instead of being raised from ground level. All concrete was mixed at the contractor's high-level plant and transported, generally, by train and 25-ton

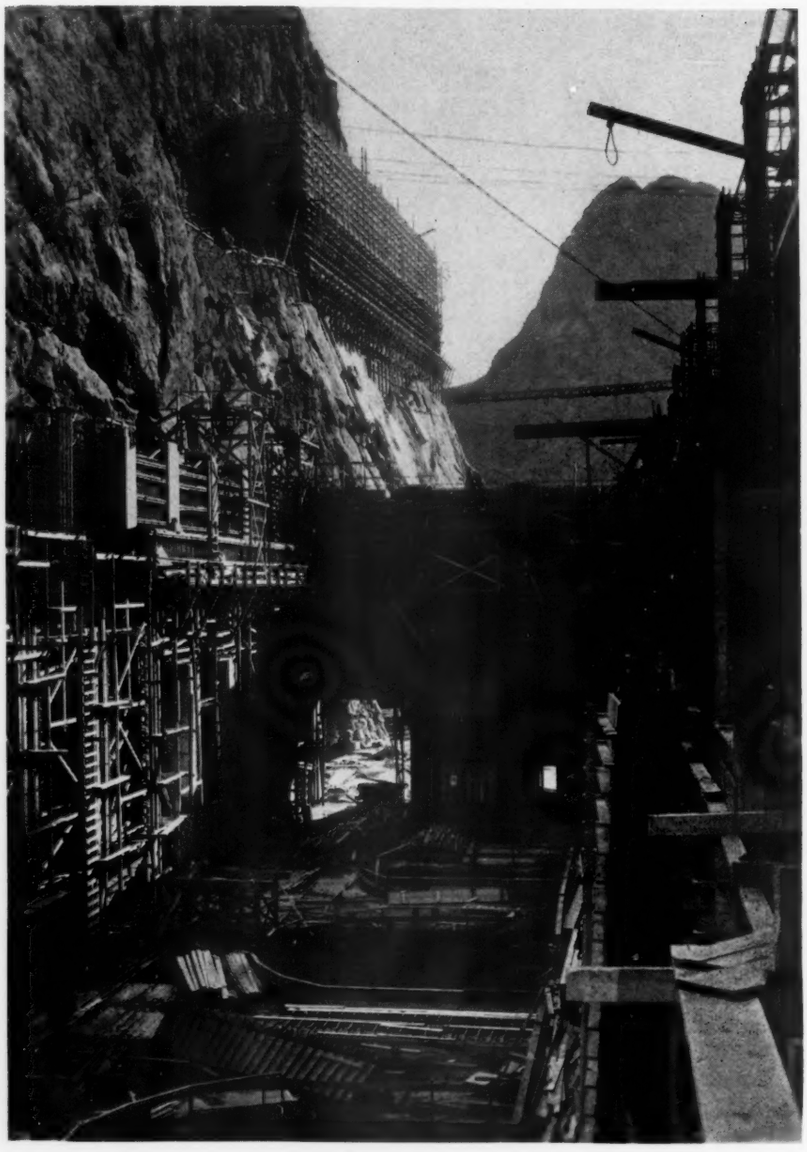
cableway in 4-cubic-yard buckets of the spout-dump or agitator type. Compressed-air and electric vibrators were used during the pouring of all wall, column, and beam concrete. Among the materials that already have been placed in the huge structure are 240,000 cubic yards of concrete, 22,000,000 pounds of reinforcing steel, and eleven miles of pipe and conduit.

The roofing steel—with many trusses 73 feet long, 13½ feet high, and weighing 75,000 pounds—was first lowered to a landing platform at generator-floor elevation and then raised into position by the contractor's cableways, the track cable being lowered 100 feet at the center of the span so that it might safely carry the load. The structural steel in the roof has a combined weight of 11,600,000 pounds and is overlain by a composition, 4½ feet thick, consisting of alternate layers of reinforced concrete and sand and gravel topped by a waterproofing layer of bituminous-sand mastic.

The installation of power-plant machinery by Government forces is now concentrated on four 115,000-hp. units in the upstream end of the Nevada wing, on two station-service units of 3,500 hp. each in the central section—all of which will be operated by the Bureau of Power & Light of the City of Los Angeles, and on one 55,000-hp. unit in the downstream end of the Arizona wing that will be operated by the Southern Sierras Power Company. Work on the placing of two 115,000-hp. units for the Metropolitan Water District of Southern California is not expected to get underway until 1936, and the remaining ten units, making an ultimate capacity of 1,835,000-hp., are to be added within the next few years as they may be required to keep pace with the increasing demand for power. The first electricity will probably be produced in the spring of 1936.

In order more easily to visualize the operation of the plant and to understand the reason for such a large structure, let us in imagination visit the power house as it will appear when finally completed. But before starting, it might be well to follow, in a general way, the transformation of power from falling water to electrical energy and the route of the electrical circuit from the generator terminals to the transmission lines. As the several units vary primarily only in size, a description of the operation of one of the fifteen 115,000-hp. units will suffice.

Water from the reservoir flows through gates in one of the four intake towers into a 30-foot-diameter pipe, the penstock header, and thence downstream to four 13-foot-diameter pipes, the power penstocks. If the operator desires, it may be continued past the penstocks to needle valves in outlet works, thus by-passing the power house. Down one of the power penstocks it goes to and through a 14-foot-diameter butterfly valve in the power plant, and thence to the spiral scroll case of the turbine. Speed vanes and wicket gates—24 of them—in the inner rim of the scroll case automatically regulate the amount of water reaching the turbine runner where the water's energy, derived from mass and velocity, is transformed into mechanical energy by rotating the horizontal runner and its vertical shaft. With flow velocity greatly reduced, the water passes peacefully out to the tailrace through the center of the turbine, the turbine draft tube, and the discharge liners.



WITHIN THE POWER HOUSE

Looking downstream from within the Arizona wing, showing positions for two of the generator units. The Arizona canyon-wall outlet works may be seen under construction above.

The mechanical energy thus developed by the turbine is transmitted through an interconnecting shaft to the generator rotor which, revolving in an electromagnetic field, produces electrical energy. This electromagnetic field is created by two generators, termed exciters, mounted above the main generator and rigidly connected on the main shaft. The lower one, the main exciter, furnishes the field for the main generator, while the pilot exciter, which is compound wound and self-excited, furnishes the field for the main exciter.

For those interested in figuring "how much"—at 100 per cent efficiency, 1 cubic foot of water falling 8.81 feet in one second will develop 1 hp., or 746 watts of electricity. The maximum head on the turbines will be 590 feet, or an average of 530 feet and a minimum of 420 feet. The rate of water flow through a turbine will vary from 2,000 to 3,000 cubic feet per second.

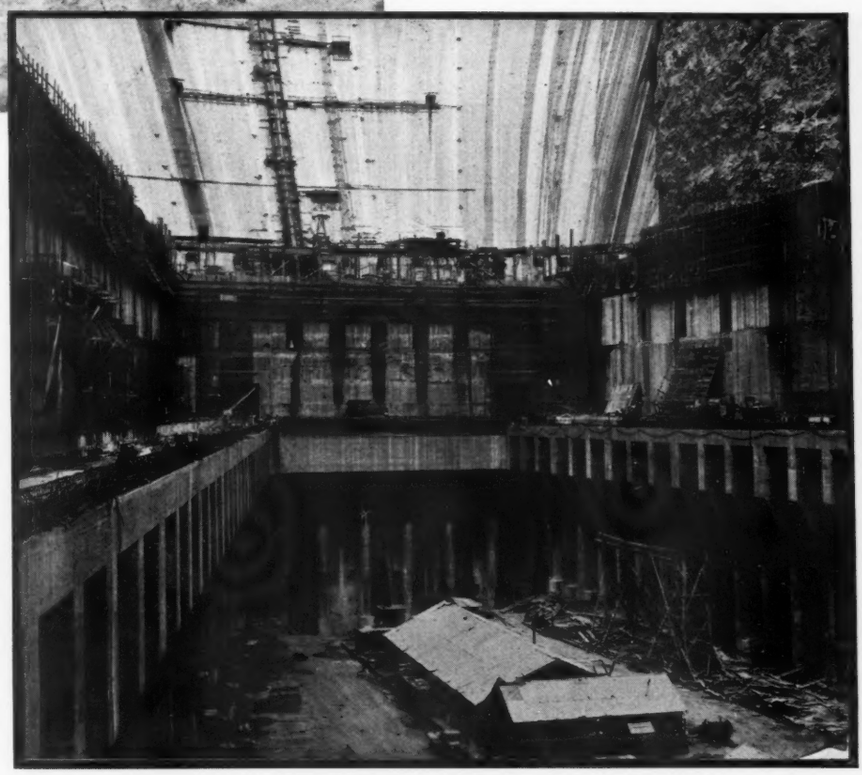
The actual operation of a turbine, however, is not so simple as just described, for in order to maintain constant frequency the energy applied to the turbine must be regulated to suit the load on the generator. This is accomplished by a governor of the fly-ball type which controls the flow of oil

The butterfly valve at the lower end of the 13-foot penstock is closed only when it is desired to cut off all flow of water to the turbine and is not used for regulatory purposes. The valve leaf is swung to open or closed position by a rotor to which oil is supplied by a pump at 1,000 pounds per square inch pressure.

Now let us follow in a schematic manner the flow of electrical energy from the generator terminals to the transmission line. Leaving the 3-phase, 60-cycle, 82,500-kva. generator terminal at 16,500 volts, it passes through the generator-voltage oil circuit breakers to the 23,000-volt, 4,000-ampere bus structure. From there is goes to three 55,000-kva., single-phase transformers outside of the power plant where it is raised to 287,500 volts for transmission purposes. From the transformer it is carried up and out of the canyon on an overhead high-voltage circuit to a switchyard located on the Nevada side of the canyon and approximately 1,500 feet from the canyon rim. By using different combinations of high-voltage oil circuit breakers in the switchyard the current may then be directed by way of the selected transmission circuit to Los Angeles, where it is received at 275,000 volts. Each generator

TAKING FORM

Although dwarfed by the dam and canyon walls, the U-shaped power house is in reality a huge structure. Equivalent in height to a 19-story building, it has an aggregate length of more than a quarter mile. Each wing section is 150 feet wide. Within the plant will be ten acres of floor space, while the roof area will equal four city blocks. These views show the power house in course of construction.

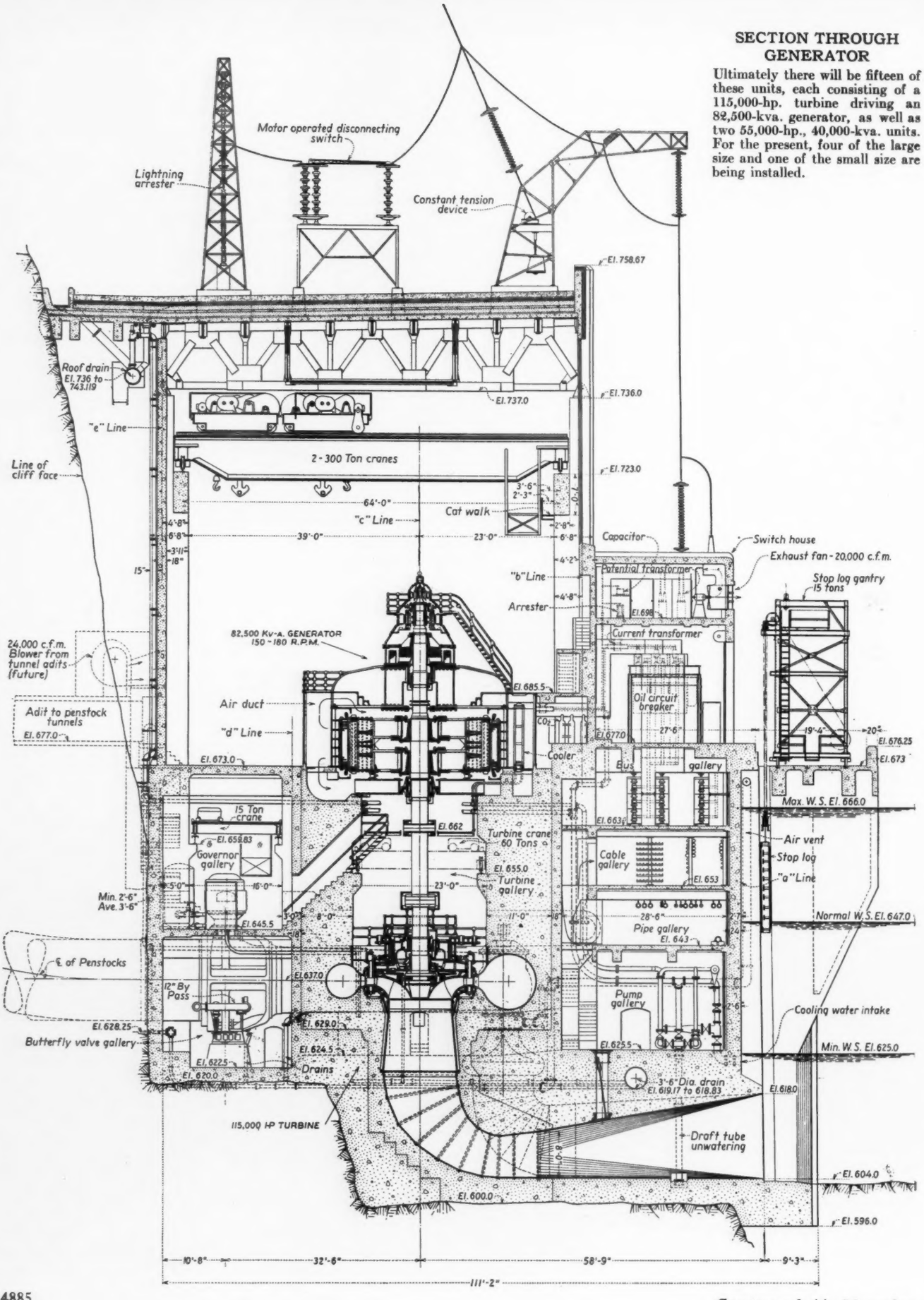


to the servo-motor cylinders which, in turn, open or close the wicket gates and control the flow of water through the turbine. The fly-balls of the governor are driven by a synchronous motor that receives its power from a small generator mounted above the main generator and on the same shaft. A change in the speed of the generator causes a change in motor speed and, consequently, a change in the position of the wicket gates.

Should an outage or other disturbance in the electrical circuit necessitate an emergency shutdown, and thus a sudden closure of the wicket gates, the turbine pressure-regulator valve situated at the upstream side of the turbine will open and the water by-pass the turbine, escaping through the relief valve to the tailrace and thus preventing excessive pressure rise in the penstock. The movable part of the relief valve is a cylinder and needle that travels upward to open and then gradually closes, thus conserving water.

SECTION THROUGH GENERATOR

Ultimately there will be fifteen of these units, each consisting of a 115,000-hp. turbine driving an 82,500-kva. generator, as well as two 55,000-hp., 40,000-kva. units. For the present, four of the large size and one of the small size are being installed.



may be operated from a control cubicle placed near it or, by throwing a control transfer switch to the proper position, from the main control benchboard on the top floor of the central section of the power house.

Power for project lighting and for numerous other plant purposes is supplied by two 3,500-hp., 3,000-kva. station-service units installed at the upstream ends of the power-house wings and on the same floor as the main generators. These units differ from the others in that each is of the horizontal-shaft, impulse type equipped with two bucket wheels, two nozzles and needles, and with two shut-off gate valves of the follower ring type. Their penstocks are of 24- and 36-inch-diameter piping and are connected to the four upstream penstocks—one from each of the four header systems.

Governors operating on the same principle as those described in connection with the larger units automatically regulate the flow of water to the turbine buckets by opening or closing the needle valves in the nozzles. The valves that shut off the water for the station-service penstocks are closed or opened by hydraulic cylinders actuated by water direct from the penstocks.

The characteristics of the 3,000-kva. generators are similar to those of the larger units. Electricity produced at 2,400 volts is passed through oil circuit breakers and switchgear to several groups of transformers which serve, respectively, for lighting the power house, switchyard, dam, outlet works, and Boulder City; for operating intake-tower gates, valves in outlet works, stoney gates, and oil-handling equipment; and for operating the various power-plant auxiliaries such as butterfly-valve and governor oil pumps, generator and turbine lubricating pumps, power-house cranes, elevators, air compressors, as well as ventilating, heating, cooling, and machine-shop equipment. For the last-mentioned group of services the current is stepped down to 460 volts—additional transformers still further reducing it to 115 volts for the control of a few other unit auxiliaries.

Power for oil circuit breakers, disconnecting switches, generator relays, carbon-dioxide fire-extinguishing control valves, turbine shut-down and starting solenoids, and for emergency power-plant lighting and miscellaneous equipment is provided by 120-cell storage batteries charged by three motor-generator sets. Direct current at 125 volts is supplied by a 60-cell battery and two motor-generator sets for the valves of the station-service units, for indicator lamps on the panel boards, for the annunciator systems, and for various unit auxiliaries.

Now we are ready for our imaginary tour of inspection of the power house. For our purpose the trip will take us through only the central section and the Nevada wing as they will be in the not far distant future when all the units are installed. We shall not see the downstream end of the Arizona wing with its 55,000-hp. turbine, 40,000-kva. generator, and accessories.

We drive from Boulder City over a smooth oil-surfaced highway, and park our car near the Nevada abutment of the dam. We then walk out on the dam crest for about one third of its length to the second of the four graceful towers that rise above the downstream parapet, stopping for a few minutes *en route* to gaze appreciatively upstream at the four intake towers and at the emerald-green lake and then downstream at the power house far below with the cliff-dwellerlike structures of the canyon-wall outlet works beyond.

Inside the tower, we step through heavy bronze doors into a waiting elevator cage, drop smoothly downward from the dam crest—which is 1,232 feet above sea level—past the dam inspection galleries at elevations 1,220, 975, 875 and 780, and in less than two minutes stop 44 stories below at elevation 705. After passing through the door—this time of aluminum—into a well-lighted lobby we turn right-about and walk through a tiled and stuccoed gallery for a distance of a block and a half to the downstream face of the dam and into the central section of the power plant.

Turning to the right, we follow a corridor on to a wide balcony along the face of the dam which extends 60 feet across the generator room. The floor of this room—of beautiful terrazzo—is 32 feet below our balcony, and the ceiling, supported by massive structural-steel trusses, is 45 feet overhead. Two 300-ton cranes move easily above us; but the focal points of interest are the huge cylindrical generators with their dome lights directly opposite us. There are eight of them spaced on 62½-foot centers and extending from the river wall 53 feet into the room—their form and hum of motion the perfect embodiment of power.

The generators are air cooled, and the enclosures around them are air- as well as dust-tight, so that fire in any one of them may be immediately extinguished by the injection of carbon-dioxide gas. Speaking of air-cooling, you will find that the temperature in all the power-house rooms is pleasantly cool even though thermometers outside may register 128°F. in the shade. The wings are ventilated by fans that take air from the penstock tunnels and force it through the various galleries, while the rooms in the central section are air conditioned by individual surface coolers through which cold water is circulated.

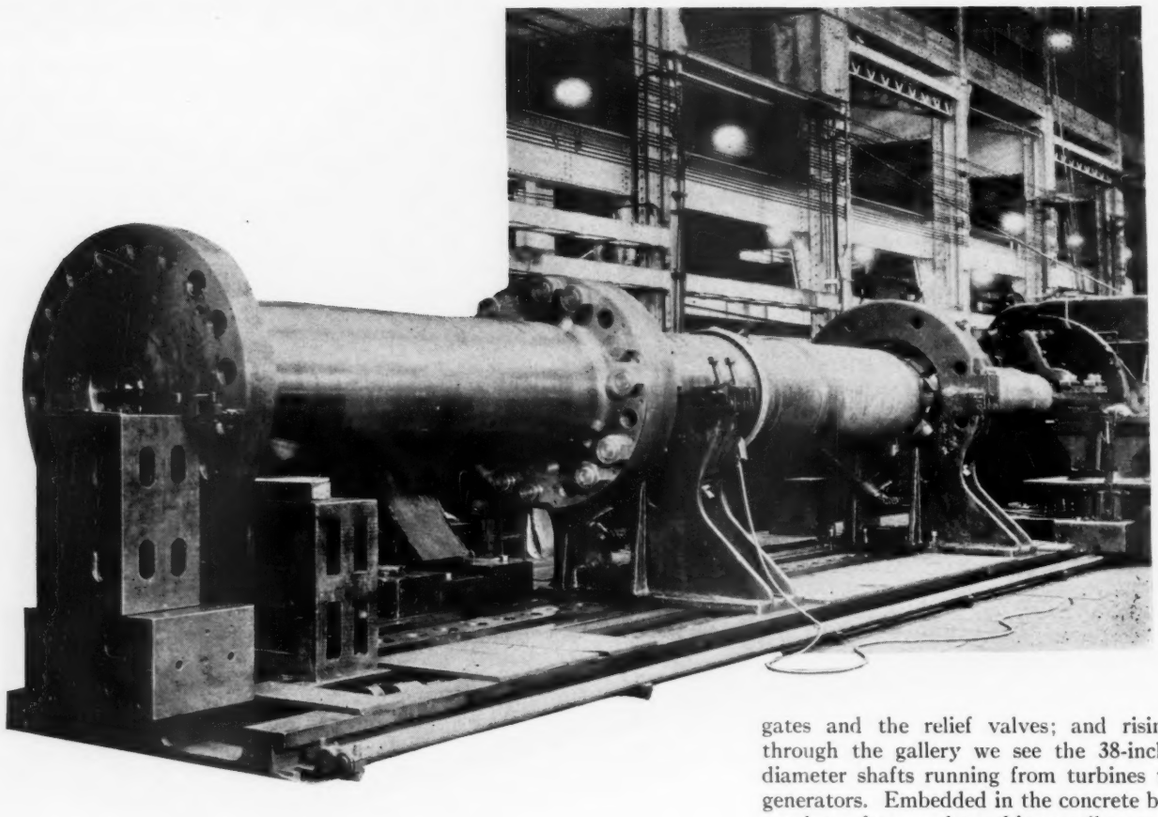
Twenty feet beneath us, and running 620 feet to the downstream end of the generator room, is another balcony. On it and at each generator are control and excitation cubicles containing control boards for separate-unit operation. Fastened to the walls on each side of the room we note the panels of multicolored lights and the horns and bells that comprise the annunciator and signal systems which call operators to the telephone or sound an audible alarm in case of trouble in the unit operation.

One of the station-service units is at our end of the room near the canyon wall. It occupies a space 21 feet square and 6 feet high. The two impulse wheels of the turbines are mounted on a horizontal shaft and drive the 3,000-kva. generator set between them. Control boards are directly behind the unit in wall recesses.

Returning to the power-house elevator near our end of the balcony we are lowered 73 feet—six stories—and, upon leaving the cage, stop to look downstream through the long line of arches between the rooms in the pipe gallery which extends the full

NEARING COMPLETION

A picture taken last May when water storage began. By comparing it with the view on page 4882, it will be seen that the structure is fast nearing its ultimate appearance.



MAKING THE EQUIPMENT

The hugeness of the generating units is brought out forcefully by the pictures on this page and on the facing one. Above is a generator-shaft assembled for inspection in the factory of the Westinghouse Electric & Manufacturing Company. At the right is shown the spiral steel casing for one of the 115,000-hp. turbines in the Allis-Chalmers plant at Milwaukee.

length of the wing. Here are pipes and valves for miscellaneous purposes as well as pumps which are used to supply water from the tailrace for generator cooling and to evacuate water from the draft tubes in case of repairs or when it is desired to operate the generator as a synchronous condenser. To our left we see the station-service penstock running the length of the central section.

Walking through a passageway toward the cliff wall we enter the butterfly-valve gallery. There at the ends of the penstock pipes are the eight huge valves, each of which with its massive concrete base almost fills a space 15x16 feet in diameter and 20 feet from floor to ceiling. One of these valves with its operating rotor that projects into the governor gallery overhead weighs 420,000 pounds.

Retracing our steps to the elevator shaft we climb nearby stairs to elevation 645.5 and, going toward the cliff wall, we find ourselves in the governor gallery. Here we inspect one of the oil-pressure-operated rotors that move the butterfly-valve leaves, each of which we learn is cylindrical in shape, 7 feet 3 inches in diameter, and 9 feet high. A control panel is mounted on each rotor, and its motor and oil pump are installed at the base. Other equipment in the governor gallery—which, incidentally, has a 26-foot-high ceiling and is 437 feet long—are the lubrication control panels for the turbines and generators, the 460-volt control panels for the auxiliaries of each unit, the thermal board with its thermometers that register the temperature of the unit bearings, a turbine flow meter for recording the water flow, and the governor-oil pressure tanks and actuators. The latter contain the fly-ball equipment, numerous gages and valves, oil pumps and motors, and control apparatus.

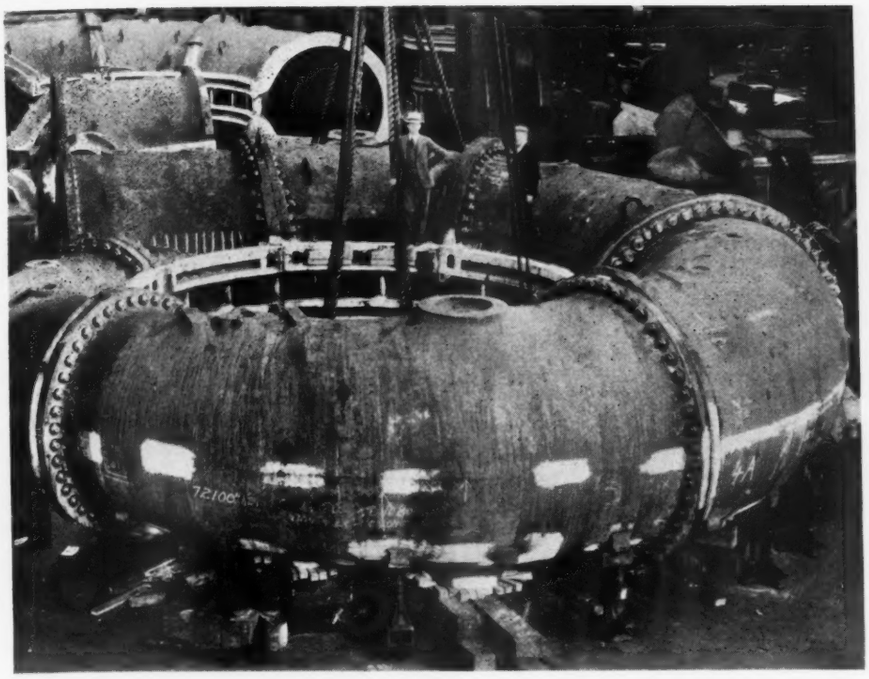
Pumps for conveying dirty oil to the filter plant from governors, transformers, circuit breakers, and lubricating-oil sumps are situated at the downstream end of the gallery. At the upstream end are the circuit breakers and reactors in the line from the 16,500-volt transfer bus in the bus gallery to the 16,500/2,300-volt transformers and the 2,300-volt switch gear at elevation 717.7. This circuit will supply power to the 2,300- and the 460-volt power circuits in case the station-service units are not operating.

Walking toward the center of the wing and going down a few steps we reach the turbine gallery at elevation 643. Here are the servo-motors and shifting rings for opening and closing the turbine wicket gates and the relief valves; and rising through the gallery we see the 38-inch-diameter shafts running from turbines to generators. Embedded in the concrete beneath our feet are the turbine scroll cases—40 feet across, 10 feet in maximum outer diameter, and weighing 245,000 pounds—as well as the relief valves of spherical outer form. They are 11 feet in diameter, and their needle valves are approximately 6 feet in diameter.

Passing onward toward the river wall we enter the pipe gallery—another long room unobstructed by partitions and extending the full length of the wing. In it are pipes and more pipes, large and small, some for compressed air, others for service and cooling water, some are oil headers, and others are for Boulder City supply.

Walking toward the dam we come to the pipe shop in the central section where are situated three centrifugal pumps for Boulder City water supply, three deep-well sumps for lifting drainage water from the dam and the power house into the tailrace, and three compressors and pressure tanks which provide air for evacuating water from the turbine draft tubes, for actuating the generator air brakes, and for general use in the machine shop and elsewhere. In rooms across the face of the dam we find the 2,400- to 240/120-volt lighting transformer banks, the 2,400- to 480-volt power transformers, and four 460-volt distribution panels. Two of these connect with the unit-auxiliary boards in the wings and the other two with the boards operating miscellaneous station-service equipment.

Returning to the Nevada wing we climb again, but this time only 10 feet to the cable gallery, at elevation 653, which is another long room like the pipe gallery. As we enter we pause a moment to inspect the



250-volt d-c. and the 460-volt a-c. unit-auxiliary distribution boards which are set in recesses along the inner wall. The cabinets contain air circuit breakers for automatic switching from 460-volt a-c. to 250-volt d-c. In the event of an outage in one of the 460-volt circuits furnishing power to some unit auxiliary, a relay starts to operate, thus cutting in the 250-volt d-c. supply. In the center of the gallery are tier upon tier of racks, while to one side, hanging on steel pillars as well as along the river wall, are row upon row of conduits. On the racks are the control cables—the nervous system of the power plant. We follow them to the central section where they turn riverward up a ramp and then, near the middle of the building, turn toward the dam through a low gallery at elevation 665.2. At the dam face they abruptly disappear upward in a shaft that we later learn opens into the cable racking room at elevation 717.67.

Retracing our steps to the first stairs in the cable gallery we climb another 10 feet to the bus gallery—a duplicate in size of the one we have just left. Near the center of the room are the pairs of transformer buses and against the river wall the generator transfer bus. These buses are designed to carry 4,000 amperes, and they operate at 16,500 volts. They are made up of two 6-inch copper channels placed flange to flange, forming a 6-inch hollow square section, and each phase is mounted on porcelain insulators and inclosed in a nonmagnetic metal covering. Also in this gallery, and located along the inner wall, are the generator neutral-grounding circuit-breakers and reactors.

Up 10 feet more and we are on the generator floor at elevation 673. As we have already seen this wing room from the balcony at elevation 705, we shall casually inspect the completely equipped machine shop that takes up nearly all that part of the central section and then pass through the wide doorway of the shop out on to a wide platform that runs the full length of the wings and central section and connects with the cableway landing platforms at the downstream ends of the power house. There are three tracks on the wing platforms—the one nearest the river being of 12-foot gauge and the two others of 4-foot-8½-inch gauge. The former serves a 15-ton gantry crane that places bulkheads across turbine draft tubes when they are to be unwatered, and on it also travels a 180-ton car used for transferring transformers and oil circuit breakers.

The power transformers and the generator oil circuit breakers are erected on another deck along the power-house wall and 4 feet above where we are standing—all these pieces of equipment being mounted on flanged-wheel trucks. Switch houses completely inclose the circuit breakers so that any fire in the breakers can be quickly extinguished by means of carbon-dioxide gas.

Closer examination of one of the 55,000-kva. transformers reveals what an enormous piece of machinery it really is. Substantially taking up the 24x22x32-foot inclosure, it weighs, when filled with oil, more than a third of a million pounds. Heat is removed from the oil by water cooling coils. Oil is replaced periodically from the filter plant—the old oil being returned for treatment to that plant which is located in the upper construction adits through which the 30-foot-diameter pipes were taken into the header tunnels.

We stop a minute to admire the modernistic effect of the power-house exterior and to remark upon the cool air current that rises from the clear, sparkling water of the tailrace. We then return to the elevator in the machine shop and ride up to the two huge control rooms at elevation 743 in the central section. They occupy the middle 62x117 feet and contain the auxiliary, main-station-service, and supervisory control boards. Most of the operations of the power plant are recorded here by various meters, and the principal circuits can be controlled from one or the other of the boards. Orders may also be given from this station to all operators by the annunciator and telephone systems. Elsewhere on this floor are the automatic and carrier-current telephone rooms (the City of Los Angeles uses the transmission cables for telephone service) and the 80-cell telephone battery.

Now we walk downstairs to the floor at elevation 730.33 where we find the terminal boards for all the control boards just mentioned and, along the river wall, a group of offices, including those of the plant superintendent and watermaster. Down another flight of stairs at elevation 717.67 and in the center near the dam are the two 120-cell 250-volt storage batteries, the 60-cell 125-volt storage battery, five motor generator sets, a water still, and a battery-control switchboard. Also in the center of this floor are cables which come down on to racks from the terminal boards above and then enter the shafts through which they either drop to the cable gallery or rise to the top of the power house and pass into and through the control-circuit tunnel to the switchyard half a mile away and 1,500 feet back from the Nevada rim. The switchboard for distributing 2,300-volt current to various places throughout the power house is on the same floor in a long room next to the river wall.

One more flight down and we are back at elevation 705 where we began our tour of inspection of the power house. We now retrace our steps and take the elevator to the dam crest high above. We are probably pretty tired, too, as we have been in the plant several hours, have walked more than a mile, and have climbed up and down the stairs of what is equivalent to a 12-story building.

It is not to be expected that all the purposes and the interrelationship of equipment and control can be entirely understood after one short trip, but it is hoped that an impression has been gained of a smoothly operating unit producing a tremendous amount of power. The entire project—dam, power house, and related works—is truly a monument to the scientific skill and engineering ability of the Bureau of Reclamation, of which Commissioner Elwood Mead is administrative head; R. F. Walter, chief engineer; S. O. Harper, assistant chief engineer; L. Savage, chief designing engineer; L. N. McClellan, chief electrical engineer; and Walker R. Young, construction engineer for Boulder Dam and power plant.

LIGHTED HALF THE WORLD

THE names of Edison and Steinmetz are known to every high-school student, but probably few persons outside the electrical industry ever heard of another wizard of amperes and volts—one Oscar Junggren. Not until Mr. Junggren died was the public at large informed how important a figure he had been in the realm of applied electricity. The General Electric Company, for which Mr. Junggren worked for 43 years, credits him with having designed the steam turbines that now generate nearly half the world's supply of electricity. As chief designing engineer of the company, he collaborated with W. L. R Emmet, chief engineer, in planning and constructing the first large Curtis turbine, a machine that ushered in a new era in the generation of power. Rated at 5,000 kw., it was exactly ten times more powerful than any turbine previously built.

All told, Mr. Junggren held 130 patents. During the eight years from 1924 to 1932, he produced 30 turbines—an average of one every four months, and each represented an entirely new design. This period of his career was characterized not only by a prolific output but also by an amazing improvement in the performance of the machines he turned out. The advance was so great that the quantity of electricity that could be obtained from a given amount of coal was more than doubled.

DRILL INVENTOR DIES

FREDERIC A. Halsey, the last of the old school of inventors who contributed to the development of the rock drill, died last month in New York at the age of 79. Mr. Halsey was the originator of the "Slugger" drill, a tripod-mounted, piston-type machine with air-thrown valves. Patents on it were issued to him on March 11, 1884, and were assigned to the Rand Drill Company, by which he was employed and of which he later was general manager. The "Slugger" drill did not greatly influence the design of the modern rock drill, but it served well in its day and was manufactured for many years.

Mr. Halsey veered away from the compressed-air industry in 1894 to become associate editor of *The American Machinist.* He was editor of that publication from 1907 to 1911, and editor emeritus from 1911 until his death. Mr. Halsey actively opposed the introduction of the metric system in America. He was the author of a dozen or more technical books. His extensive library included many volumes on mechanical subjects that have long been out of print, and these were bequeathed by him to the American Society of Mechanical Engineers of which he was a member.

THE CHANGING ROCKIES

HOW old are the Rocky Mountains? No one can answer this question with exactness, but Dr. Wallace Atwood, president of Clark University, has contributed some interesting observations on the subject. He has been able to trace back their history roughly 30,000,000 years, and has reached the conclusion that during that time three ranges have been formed and partly leveled. That is to say, there have been three distinct and separate periods of uplift in the same area.

According to Doctor Atwood, a long period of erosion has followed each upheaval, wearing the mountains down to their stumps, after which a new range has been formed. The third period of wearing away is now in progress, and it is reasonable to assume that it will be followed by a new mountain-forming movement which will rear another chain of peaks. If all the material that has been removed during the eras of reduction could be put back on the mountain tops, their general level would be from 15,000 to 20,000 feet higher than at present. In other words, we should have some peaks rising to altitudes of 30,000 to 35,000 feet.

THE "AGE OF STEEL"

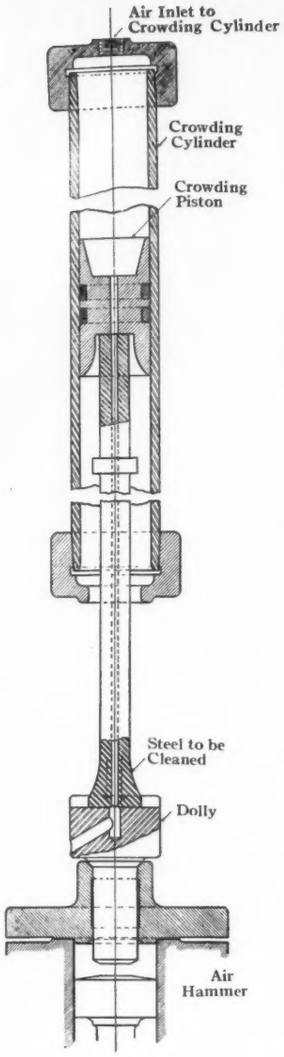
BY WAY of refuting the occasional statements that the "Age of Steel" is passing, William A. Irwin, president of the United States Steel Corporation, recently cited some simple facts that virtually everyone knows but that hardly anyone ever thinks about. "The age of this and the age of that," said Mr. Irwin, "are convenient expressions for marking mileposts of civilization, but they fall short of measuring some of the economic factors in which we are most interested."

He then pointed out that more stone is now used than during the "Stone Age," that bronze is employed more extensively and in more varied forms than in the "Bronze Age," and that even candles are burned in far larger numbers today than when they were the chief means of illumination.

In view of these truths, Mr. Irwin expressed complacence over the future of steel, and then proceeded to mention a few of the countless new uses of steel that have sprung up in the face of the movement to apply nonferrous materials in greater quantities. Streamlined passenger trains, street cars, trucks, and buses are continually adding to the demand for high-tensile steels. Consideration of fire hazards is leading to the adoption of steel superstructures for ships. A few years ago steel partitions were introduced in buildings: now entire interiors are being made of it, and houses built almost wholly of steel are coming into favor. Among the newer interesting applications of steel is its use for beverage containers. One of the large can companies made an announcement not so long ago to the effect that it expects to be producing 4,000,000 beer cans a month by the end of the year.

What is true of steel is true of all other basic materials of merit. Human ingenuity and technical advancement combine to uncover new fields of utility for them; and their aggregate service to mankind grows ever greater.

Plug Remover for Hollow Drill Steel



WHERE hollow drill steel in quantity is in daily use, the equipment in the blacksmithshop in which they are sharpened and otherwise reconditioned may in future include an air-operated device of recent introduction that has for its purpose the removal of plugs from such steel. The Pan-American Drill Steel Cleaner, as it is called, is the invention of O. E. Schiffer and is being manufactured by the Pan-American Engineering Corporation, Ltd. Before it was put in production for general application it was tried out for about a year in the Lava Cap Mine near Grass Valley, Calif.

The machine takes up little floor space, and consists essentially of an upright metal frame at the bottom of which is a dolly and an air hammer and to the uppermost end of which the cleaner, in the form of a tube, is pivoted above midlength so that it can be swung out to facilitate the insertion of the steel. With a plugged drill steel in position, as shown in the accompanying line drawing, compressed air is admitted into the crowding cylinder at the top of the machine, causing the piston to force the steel firmly against the dolly. Following that, the pneumatic hammer is put in motion. By delivering a succession of rapid and powerful blows to the dolly, the hammer sets up violent, vertical vibrations in the steel and these, in a surprisingly short time, break up the plug. An opening in the dolly of a diameter the same as that in the steel permits the fragments to drop out and clear of the machine. Any remaining particles clinging to the inner surfaces are forcibly ejected by the compressed air in the crowding chamber as it blows through the hole in the piston and the bore of the steel in seeking to escape. It is claimed that the entire operation takes only a few seconds, except in very stubborn cases. The air used is at a pressure of from 90 to 100 pounds per square inch, the same as that required to run the drill itself.

Moleskin Cloth for Waterproofing Hydraulic Structures

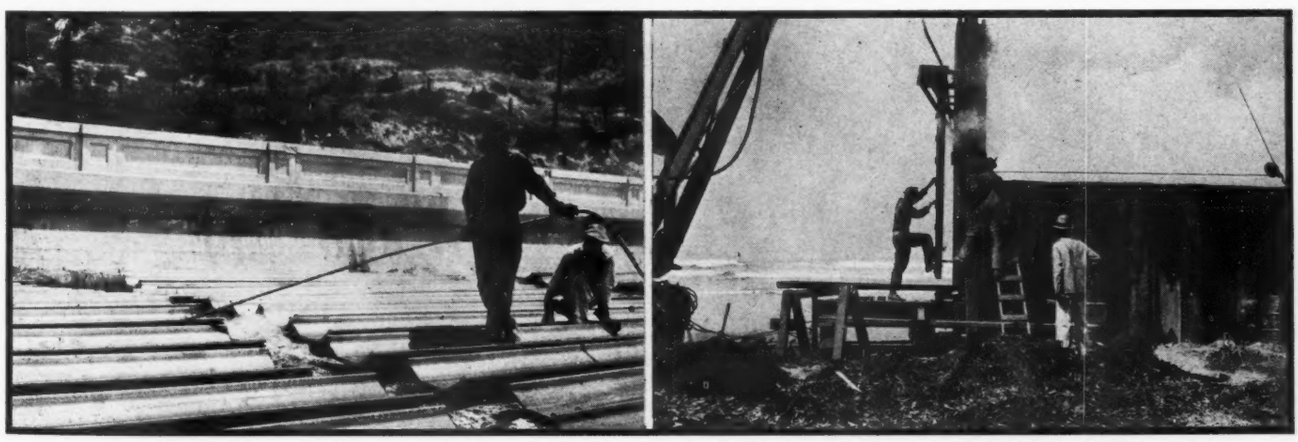
MOLESKIN cloth has been used by the French engineer G. Menier for waterproofing various hydraulic structures such as cofferdams, needle dams, etc. In a paper recently read by him before the French Academy of Sciences he tells of his experiences with this material. Its first application was in connection with a cofferdam, more than 18 feet high, that was built to effect the replacement of a hydraulic turbine having a diameter of 23 feet. The structure consisted of a single line of wood sheet piling, the outer surfaces of which were protected with this fabric. It was easily placed by unrolling bolts of it—the cloth being weighted down for the purpose with cast-iron rods attached to the free ends. When the cofferdam was unwatered the material was pressed tight against the sheet piling, thus effectually preventing leakage. Again, in waterproofing a needle dam on the Marne during a drought, a covering of thin moleskin was applied; and inspection after four months of service proved the seal to be tight. It is also serving to check seepage through flashboards on the crests of dams. Moleskin cloth is available in two thicknesses.

For Highway Protection

Near Los Angeles, interlocking steel sheet piling is being employed in an effort to protect a shore-line highway from the battering of the ocean waves. Highway engineers express the belief that this type of structure is going to prove an economical safeguard for embankments extending along exposed waterfronts.

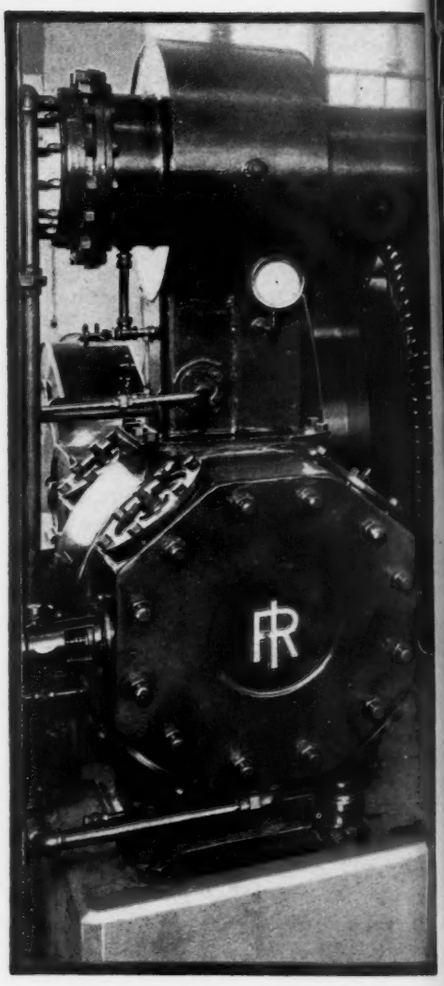
After many experiments, the engineers in charge developed an interesting method of protecting the steel piling from the corrosive action of salt water. After rust and scale had been removed, quick-drying prime coats were applied and, when thoroughly dry, a hot asphaltic coating was sprayed on to a thickness of ⅛ inch.

It was soon found that the coating began to wear off wherever pebbles were hurled against it by the waves. Accordingly, a fast-drying primer was sprayed on it, after which hot asphaltic coatings were applied, also with air guns. Slightly damp beach sand was then thrown against the asphalt and the process repeated until a layer about ¼ inch thick had been built up. Indications are that this treatment will enable the piling to resist both corrosion and the erosive action of the waves. The pictures below show asphalt being applied before driving (left) and sheet piling being forced into position.



EXPLOSIONS *caused*

That's why it is important to make sure your oils are right!



UNSUITABLE OILS, excessive oil feeds, and dirty air will build up deposits of carbon without warning. Then some fine day—bang!—and another compressor is wrecked—perhaps with the sacrifice of human lives.

This often happens when oil-saturated, highly compressed air hits these incandescent carbon deposits. The best safeguard is to choose oils that will minimize carbon deposits on valves, passages, ports, and airlines—and *feed them sparingly.*

Texaco Cetus, Texaco Alcaid, Texaco Algol, and Texaco Ursa are exceptionally free from carbon-forming elements. Because of their extreme oiliness they maintain a uniform film and yet can be fed in very small quantities. Their cleanness and stamina insure lowered maintenance expense—less time out for cleaning—and *less danger!*

Your men know what your compressors are up against. The Texaco representative knows which lubricant is best suited to each specific condition. Letting them work together will go a long way toward safety, efficiency and economy.

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